

...and some of the Temple of Jupiter at Baalbec.

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PRINCIPLES
OF
G E O L O G Y :

OR, THE
MODERN CHANGES
OF THE EARTH AND ITS INHABITANTS,
CONSIDERED AS ILLUSTRATIVE OF GEOLOGY.

BY
CHARLES LYELL, ESQ. F.R.S.

" Amid all the revolutions of the globe, the economy of Nature has been uniform, and her laws are the only things that have resisted the general movement. The rivers and the rocks, the seas and the continents, have been changed in all their parts ; but the laws which direct those changes, and the rules to which they are subject, have remained invariably the same."

PLAYFAIR, *Illustrations of the Huttonian Theory*, § 374.

IN THREE VOLUMES.

VOL. I.

THE SIXTH EDITION.



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601.

TO

W. LONSDALE, ESQ.

GEOLOGICAL SOCIETY OF LONDON.

MY DEAR LONSDALE,

I have ventured to dedicate this work to you without asking your permission, fearing that you might have declined a public acknowledgment of what I owe you for frequent assistance, and knowing the habitual generosity with which you are willing to allow the results of your own labours to merge in the writings of others. But you will, I trust, excuse me for taking this opportunity of expressing my admiration of your talents, and of your unwearied and most disinterested devotion to the cause of Geology.

Believe me,

My dear Lonsdale,

Yours very sincerely,

CHAS. LYELL.

London, June 15. 1840.

P R E F A C E.

THE original MS. of the Principles of Geology was delivered to the publisher in 1827; but the greater portion of it was then in an unfinished state, the chapters on the early history of Geology and those on “the Inorganic Causes of Change,” being the only ones then nearly ready for the press. The following were the dates when the successive volumes and editions finally appeared:—

1st Vol. in octavo	-	-	-	Jan. 1830.
2d Vol.	do.	-	-	Jan. 1832.
1st Vol.	2d edition in octavo		-	1832.
2d Vol.	2d edition	do.	-	Jan. 1833.
3d Vol.	1st edition	do.	-	May 1833.
New edition (called the 3d) of the				
whole work in 4 vols. 12mo.			-	May 1834.
4th edition,	4 vols. 12mo.	-	-	June 1835.
5th do.	do.	do.	-	Mar. 1837.

In July 1838, or nearly a year and a half after the appearance of the last-mentioned fifth edition, I published my “Elements of Geology” (1 vol. 12mo.), which had been written originally in the form of a supplement to the Principles. This

volume was confined strictly to Geology proper, so that it was distinct in its subject-matter from the three first Books of the Principles, which related exclusively to those recent changes of the earth and its inhabitants which are illustrative of geological phenomena. But the fourth Book of the Principles, having chiefly for its object to describe the more modern formations commonly termed tertiary, and containing also a short notice of the older rocks, occupied in some degree the same ground as the Elements, although treating of the same subjects differently. I was induced, therefore, in preparing the present edition, first to abridge, and finally to separate altogether, this concluding Book from the rest of the Principles, intending to find some future opportunity of publishing elsewhere my classification of the tertiary strata in detail, as soon as I have completed a series of investigations in which I am at present engaged. By this new arrangement, the sixth edition will be exclusively confined to the consideration of the changes now going on upon the earth in the animate and inanimate creation, and the bearing of such changes on the interpretation of geological monuments.

With a view, however, of giving still greater unity of plan to the Principles, I have thought it desirable to incorporate certain passages, formerly in the fourth Book, into the preliminary essays,

which follow immediately after the history of the progress of Geology in the first Book. In those essays I have endeavoured to give a full explanation of all the facts and arguments which incline me to believe that the forces now operating upon and beneath the earth's surface, may be the same both in kind and degree with those which at remote epochs have worked out geological revolutions; or, in other words, that we may dispense with sudden, violent, and general catastrophes, and regard the ancient and present fluctuations of the organic and inorganic world as belonging to one continuous and uniform series of events. To carry into effect the object above alluded to, many passages, and two entire chapters, have been transferred from the fourth to the first Book, which last has been thus increased by four new chapters (from the tenth to the thirteenth inclusive).

It would be tedious to enumerate all the other additions and corrections which have been introduced into the present edition, but I must mention some of the most important, in order to direct the attention of those who are already acquainted with the Principles, to what is new. It will be seen that almost all the alterations have been rendered necessary, by discoveries made, or works published, since the year 1836, when the fifth edition was written.

I had stated, on former occasions, in the first Book, that no fossil Quadruped had yet been found, and offered some remarks on the probable causes of their rarity. It will now appear that remains of this class have recently been brought to light in France, England, India, and Brazil. (See Vol. I. p. 245.)

In my account of the opinions entertained respecting former variations in climate, I mentioned several astronomical theories which had been proposed. To these are now added a new hypothesis of the late M. Poisson, respecting the unequal temperature of the regions of space, through which our sun and planetary system are supposed to have been successively carried; and a suggestion of Sir John Herschel as to the possible connection of the fluctuating splendour of certain stars with secular variations in climate. (See Vol. I. pp. 221. 223.)

In another place I have given some account of the result of certain mathematical investigations of Mr. Hopkins, in his attempt to determine within certain limits the thickness of the solid crust of the globe, by a new solution of the problem of the precessional motion of the pole of the earth. (See Vol. II. p. 431.)

I have also referred to the objections advanced by Professor Bischoff to the chemical theory of

volcanic heat * : and to Dr. Daubeny's reply †, when speaking of the causes of volcanos and earthquakes ; and the two chapters (Ch. xix. and xx. Book ii.) on this subject have been entirely recast. (See Vol. II. pp. 425—479.)

A chapter has been introduced, for the first time, on the power of river-ice, glaciers, and icebergs, to transport solid matter, and to polish and furrow the surface of rocks. The facts and illustrations contained in this chapter have been almost entirely derived from my private correspondence during the last four years, or from new publications. (See Vol. I. p. 369.)

The observations of Sir J. G. Wilkinson on the Delta of the Nile ‡ have led me to enlarge and correct the fifth chapter of the second Book (see Vol. I. p. 439.); and I have noticed elsewhere the new observations made by Niccolini and Capocci on the movement of the ground on which stands the temple of Serapis. (See Vol. II. p. 398.) In the year 1838 I caused, with Captain Grant's assistance, a survey to be made of the site of Ullah Bund and the fort of Sindree, in Cutch, which has enabled me to speak of the present condition of that district as compared to its state immediately

* Jamieson's Ed. New Phil. Journ., 1839.

† Ibid. ‡ Geograph. Journ., 1839.

after the earthquake of 1819. (See Vol. II. p. 310.)

My sketch of the geographical boundaries of volcanic regions has been improved by reference to several new works, especially the Appendix to Von Buch's new edition (Paris, 1836) of his Canary Islands. (See Vol. II. p. 121.) In treating of Mount Etna, I have availed myself of M. de Beaumont's valuable essay on the structure of that volcano, published in 1838, and of the posthumous work of Hoffmann on Sicily (Berlin, 1839). In other chapters, also, when examining into the origin of volcanic cones, and the theory of their upheaval, I have referred to the new publications of Von Buch, Abich, Dufrénoy, De Beaumont, and Hoffmann. (See Vol. II. pp. 163. 180, 181. 184.)

Lastly, Mr. Darwin's new views as to the origin of circular coral reefs or lagoon-islands, have induced me to renounce the hypothesis which I formerly advocated, that such reefs were based on submerged volcanic craters, and I have ventured to speculate on what I conceive to be the legitimate consequences of his new theory of subsidence. (See Vol. III. p. 379.)

I am still aware that there are a great variety of books of merit, especially on natural history, and of important facts communicated to the

scientific world within the last four years, of which I remain ignorant; but the reader must accept as an apology the increasing difficulty of keeping pace with the rapid progress of Geology, and the various sciences which are so intimately connected with it.

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ERRATA.

Vol. I. p. 34. *note*, for "Mr. Hallerm" read "Mr. Hallam."
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PRINCIPLES OF GEOLOGY.

BOOK I.

CHAPTER I.

Geology defined — Compared to History — Its relation to other Physical Sciences — Not to be confounded with Cosmogony.

GEOLOGY is the science which investigates the successive changes that have taken place in the organic and inorganic kingdoms of nature : it inquires into the causes of these changes, and the influence which they have exerted in modifying the surface and external structure of our planet.

By these researches into the state of the earth and its inhabitants at former periods, we acquire a more perfect knowledge of its present condition, and more comprehensive views concerning the laws now governing its animate and inanimate productions. When we study history, we obtain a more profound insight into human nature, by instituting a comparison between the present and former states of society. We trace the long series of events which have gradually led to the actual posture of affairs ; and by connecting effects with their causes, we are enabled to classify and retain in the memory a multitude of complicated relations — the various peculiarities of national character — the dif-

ferent degrees of moral and intellectual refinement, and numerous other circumstances, which, without historical associations, would be uninteresting or imperfectly understood. As the present condition of nations is the result of many antecedent changes, some extremely remote and others recent, some gradual, others sudden and violent, so the state of the natural world is the result of a long succession of events ; and if we would enlarge our experience of the present economy of nature, we must investigate the effects of her operations in former epochs.

We often discover with surprise, on looking back into the chronicles of nations, how the fortune of some battle has influenced the fate of millions of our contemporaries, when it has long been forgotten by the mass of the population. With this remote event we may find inseparably connected the geographical boundaries of a great state, the language now spoken by the inhabitants, their peculiar manners, laws, and religious opinions. But far more astonishing and unexpected are the connections brought to light, when we carry back our researches into the history of nature. The form of a coast, the configuration of the interior of a country, the existence and extent of lakes, valleys, and mountains, can often be traced to the former prevalence of earthquakes and volcanos in regions which have long been undisturbed. To these remote convulsions the present fertility of some districts, the sterile character of others, the elevation of land above the sea, the climate, and various peculiarities, may be distinctly referred. On the other hand, many distinguishing features of the surface may often be ascribed to the operation, at a remote era, of slow and tranquil causes — to the gradual deposition of sediment in a

lake or in the ocean, or to the prolific increase of testacea and corals.

To select another example, we find in certain localities subterranean deposits of coal, consisting of vegetable matter, formerly drifted into seas and lakes. These seas and lakes have since been filled up, the lands whereon the forests grew have disappeared or changed their form, the rivers and currents which floated the vegetable masses can no longer be traced, and the plants belonged to species which for ages have passed away from the surface of our planet. Yet the commercial prosperity, and numerical strength of a nation, may now be mainly dependent on the local distribution of fuel determined by that ancient state of things.

Geology is intimately related to almost all the physical sciences, as history is to the moral. An historian should, if possible, be at once profoundly acquainted with ethics, politics, jurisprudence, the military art, theology; in a word, with all branches of knowledge by which any insight into human affairs, or into the moral and intellectual nature of man, can be obtained. It would be no less desirable that a geologist should be well versed in chemistry, natural philosophy, mineralogy, zoology, comparative anatomy, botany; in short, in every science relating to organic and inorganic nature. With these accomplishments, the historian and geologist would rarely fail to draw correct and philosophical conclusions from the various monuments transmitted to them of former occurrences. They would know to what combination of causes analogous effects were referable, and they would often be enabled to supply, by inference, information concerning many events unrecorded in the defective

archives of former ages. But as such extensive acquisitions are scarcely within the reach of any individual, it is necessary that men who have devoted their lives to different departments should unite their efforts; and as the historian receives assistance from the antiquary, and from those who have cultivated different branches of moral and political science, so the geologist should avail himself of the aid of many naturalists, and particularly of those who have studied the fossil remains of lost species of animals and plants.

The analogy, however, of the monuments consulted in geology, and those available in history, extends no farther than to one class of historical monuments,—those which may be said to be *undesignedly* commemorative of former events. The canoes, for example, and stone hatchets found in our peat bogs, afford an insight into the rude arts and manners of the earliest inhabitants of our island; the buried coin fixes the date of the reign of some Roman emperor; the ancient encampment indicates the districts once occupied by invading armies, and the former method of constructing military defences: the Egyptian mummies throw light on the art of embalming, the rites of sepulture, or the average stature of the human race in ancient Egypt. This class of memorials yields to no other in authenticity, but it constitutes a small part only of the resources on which the historian relies, whereas in geology it forms the only kind of evidence which is at our command. For this reason we must not expect to obtain a full and connected account of any series of events beyond the reach of history. But the testimony of geological monuments, if frequently imperfect, possesses at least the advantage of being free from all suspicion of misrepresentation. We may be deceived in the inferences which we draw, in the

same manner as we often mistake the nature and import of phenomena observed in the daily course of nature ; but our liability to err is confined to the interpretation, and, if this be correct, our information is certain.

It was long before the distinct nature and legitimate objects of geology were fully recognized, and it was at first confounded with many other branches of inquiry, just as the limits of history, poetry, and mythology were ill-defined in the infancy of civilization. Even in Werner's time, or at the close of the eighteenth century, geology appears to have been regarded as little other than a subordinate department of mineralogy ; and Desmarest included it under the head of Physical Geography. But the most common and serious source of confusion arose from the notion that it was the business of geology to discover the mode in which the earth originated, or, as some imagined, to study the effects of those cosmological causes which were employed by the Author of Nature to bring this planet out of a nascent and chaotic state into a more perfect and habitable condition. Hutton was the first who endeavoured to draw a strong line of demarcation between his favourite science and cosmogony, for he declared that geology was in nowise concerned "with questions as to the origin of things."

An attempt will be made in the sequel of this work to demonstrate that geology differs as widely from cosmogony, as speculations concerning the mode of the first creation of man differ from history. But, before entering more at large on this controverted question, it will be desirable to trace the progress of opinion on this topic, from the earliest ages to the commencement of the present century.

CHAPTER II.

HISTORICAL SKETCH OF THE PROGRESS OF GEOLOGY.

Oriental Cosmogony — Doctrine of the successive destruction and renovation of the world — Origin of this doctrine — Common to the Egyptians — Adopted by the Greeks — System of Pythagoras — of Aristotle — Dogmas concerning the extinction and reproduction of genera and species — Strabo's theory of elevation by earthquakes — Pliny — Concluding Remarks on the knowledge of the Ancients.

Oriental Cosmogony. — THE earliest doctrines of the Indian and Egyptian schools of philosophy agreed in ascribing the first creation of the world to an omnipotent and infinite Being. They concurred also in representing this Being, who had existed from all eternity, as having repeatedly destroyed and reproduced the world and all its inhabitants. In the "Institutes of Menū," the sacred volume of the Hindoos, to which, in its present form, Sir William Jones ascribes an antiquity of at least eight hundred and eighty years before Christ, we find this system of the alternate destruction and renovation of the world proposed in the following remarkable verses : —

" The Being, whose powers are incomprehensible, having created me (Menū) and this universe, again became absorbed in the supreme spirit, changing the time of energy for the hour of repose.

" When that power awakes, then has this world its full expansion ; but when he slumbers with a tranquil spirit, then the whole system fades away. . . . For

while he reposes as it were, embodied spirits endowed with principles of action depart from their several acts, and the mind itself becomes inert."

Menù then describes the absorption of all beings into the Supreme essence, and the Divine soul itself is said to slumber, and to remain for a time immersed in "the first idea, or in darkness." He then proceeds (verse fifty-seven), "Thus that immutable power, by waking and reposing alternately, revivifies and destroys, in eternal succession, this whole assemblage of locomotive and immovable creatures."

It is then declared that there has been a long succession of *manvantaras*, or periods, each of the duration of many thousand ages, and —

"There are creations also, and destructions of worlds innumerable : the Being, supremely exalted, performs all this with as much ease as if in sport, again and again, for the sake of conferring happiness." *

The compilation of the ordinances of Menù was not all the work of one author nor of one period, and to this circumstance some of the remarkable inequalities of style and matter are probably attributable. There are many passages, however, wherein the attributes and acts of the "Infinite and Incomprehensible Being" are spoken of with much grandeur of conception and sublimity of diction, as some of the passages above cited, though sufficiently mysterious, may serve to exemplify. There are at the same time such puerile conceits and monstrous absurdities in this cosmogony, that some may be disposed to impute to mere accident any slight approximation to truth, or apparent coin-

* Institutes of Hindoo Law, or the Ordinances of Menù, from the Sanscrit, translated by Sir William Jones, 1796.

cidence between the oriental dogmas and observed facts. This pretended revelation, however, was not purely an effort of the unassisted imagination, nor invented without regard to the opinions and observations of naturalists. There are introduced into it certain astronomical theories, evidently derived from observation and reasoning. Thus, for instance, it is declared that, at the North Pole, the year was divided into a long day and night, and that their long day was the northern, and their night the southern course of the sun; and to the inhabitants of the moon, it is said, one day is equal in length to one month of mortals.* If such statements cannot be resolved into mere conjectures, we have no right to refer to mere chance the prevailing notion, that the earth and its inhabitants had formerly undergone a succession of revolutions and catastrophes interrupted by long intervals of tranquillity.

Now there are two sources in which such a theory may have originated. The marks of former convulsions on every part of the surface of our planet are obvious and striking. The remains of marine animals imbedded in the solid strata, are so abundant, that they may be expected to force themselves on the observation of every people who have made some progress in refinement; and especially where one class of men are expressly set apart from the rest for study and contemplation. If these appearances are once recognized, it seems natural that the mind should conclude in favour, not only of mighty changes in past ages, but of alternate periods of repose and disorder;—of repose, when the fossil animals lived, grew, and

* Menū, Inst. c. i. 66, and 67.

multiplied—of disorder, when the strata in which they were buried became transferred from the sea to the interior of continents, and were uplifted so as to form part of high mountain chains. Those modern writers, who are disposed to disparage the former intellectual advancement and civilization of eastern nations, may concede some foundation of observed facts for the curious theories now under consideration, without indulging in exaggerated opinions of the progress of science; especially as universal catastrophes of the world, and extinctions of organic beings, in the sense in which they were understood by the Brahmin, are untenable doctrines.

We know that the Egyptian priests were aware, not only that the soil beneath the plains of the Nile, but that also the hills bounding the great valley, contained marine shells*; and it could hardly have escaped the observation of eastern philosophers, that some soils were filled with fossil remains, since so many national works requiring extensive excavations were executed by oriental monarchs in very remote eras. They formed canals and tanks on a magnificent scale, and we know that in more recent times (the fourteenth century of our era) the removal of soil necessary for such undertakings brought to light geological phenomena, which attracted the attention of a people less civilized than were many of the older nations of the East.†

* Herodot. Euterpe, 12.

† This circumstance is mentioned in a Persian MS. copy of the historian Ferishta, in the library of the East India Company, relating to the rise and progress of the Mahomedan empire in India, procured by Colonel Briggs from the library of Tippoo Sultan in 1799; and has been recently referred to at some length

But although the Brahmins, like the priests of Egypt, may have been acquainted with the existence of fossil remains in the strata, it is possible that the doctrine of successive destructions and renovations of the world merely received corroboration from such proofs; and that it may have been originally handed down, like the religious traditions of most nations, from a ruder state of society. The system may have had its source in exaggerated accounts of those partial, but often dreadful, catastrophes, which are sometimes occasioned by particular combinations of natural causes. Floods and volcanic eruptions, the agency of water and fire, are the chief instruments of devastation on our globe. We shall point out in the sequel, the extent of many of these calamities, recurring at distant intervals of time, in the present course of nature; and shall only observe here, that they are so peculiarly calculated to inspire a lasting terror, and are so often fatal in their consequences to great multitudes of people, that it scarcely requires the passion for the marvellous, so characteristic of rude and half-civilized nations, still less the exuberant imagination of eastern writers, to augment them into general cataclysms and conflagrations.

The great flood of the Chinese, which their traditions carry back to the period of Yaou, something

by Dr. Buckland. — (Geol. Trans. 2d Series, vol. ii. part iii. p. 389.) — It is stated that, in the year 762 (or 1360 of our era), the king employed fifty thousand labourers in cutting through a mound, so as to form a junction between the rivers Selima and Sutluj; and in this mound were found the bones of elephants and men, some of them petrified, and some of them resembling bone. The gigantic dimensions attributed to the human bones show them to have belonged to some of the larger pachydermata.

more than 2000 years before our era, has been identified by some persons with the universal deluge described in the Old Testament; but according to Mr. Davis, who accompanied two of our embassies to China, and who has carefully examined their written accounts, the Chinese cataclysm is therein described as interrupting the business of agriculture, rather than as involving a general destruction of the human race. The great Yu was celebrated for having "opened nine channels to draw off the waters," which "covered the low hills and bathed the foot of the highest mountains." Mr. Davis suggests that a great derangement of the waters of the Yellow River, one of the largest in the world, might even now cause the flood of Yaou to be repeated, and lay the most fertile and populous plains of China under water. In modern times the bursting of the banks of an artificial canal, into which a portion of the Yellow River has been turned, has repeatedly given rise to the most dreadful accidents, and is a source of perpetual anxiety to the government. It is easy, therefore, to imagine how much greater may have been the inundation, if this valley was ever convulsed by a violent earthquake.*

Humboldt relates the interesting fact that after the annihilation of a large part of the inhabitants of Cumana, by an earthquake in 1766, a season of extraordinary fertility ensued, in consequence of the great rains which accompanied the subterranean convulsions. "The Indians," he says, "celebrated, after the ideas of an antique superstition, by festivals and

* See Davis on "The Chinese," published by the Soc. for the Diffus. of Use. Know. vol. i. pp. 137. 147.

dancing, the destruction of the world and the approaching epoch of its regeneration." *

The existence of such rites among the rude nations of South America is most important, for it shows what effects may be produced by great catastrophes of this nature, recurring at distant intervals of time, on the minds of a barbarous and uncultivated race. The superstitions of a savage tribe are transmitted through all the progressive stages of society, till they exert a powerful influence on the mind of the philosopher. He may find, in the monuments of former changes on the earth's surface, an apparent confirmation of tenets handed down through successive generations, from the rude hunter, whose terrified imagination drew a false picture of those awful visitations of floods and earthquakes, whereby the whole earth as known to him was simultaneously devastated.

Egyptian Cosmogony.—Respecting the cosmogony of the Egyptian priests, we gather much information from writers of the Grecian sects, who borrowed almost all their tenets from Egypt, and amongst others that of the former successive destruction and renovation of the world.† We learn from Plutarch, that this was the theme of one of the hymns of Orpheus, so celebrated in the fabulous ages of Greece. It was brought by him from the banks of the Nile; and we even find in his verses, as in the Indian systems, a definite period assigned for the duration of each successive world.‡ The returns of great catastrophes were determined by the period of the *Annus Magnus*,

* Humboldt et Bonpland, *Voy. Relat. Hist.* vol. i. p. 30.

† Prichard's *Egypt. Mythol.* p. 177.

‡ Plut. de Defectu Oraculorum, cap. 12. Censorinus de Die Natali. See also Prichard's *Egypt. Mythol.* p. 182.

or great year,—a cycle composed of the revolutions of the sun, moon, and planets, and terminating when these return together to the same sign whence they were supposed at some remote epoch to have set out. The duration of this great cycle was variously estimated. According to Orpheus, it was 120,000 years; according to others, 300,000; and by Cassander it was taken to be 360,000 years.*

We learn particularly from the *Timæus* of Plato, that the Egyptians believed the world to be subject to occasional conflagrations and deluges, whereby the gods arrested the career of human wickedness, and purified the earth from guilt. After each regeneration, mankind were in a state of virtue and happiness, from which they gradually degenerated again into vice and immorality. From this Egyptian doctrine, the poets derived the fable of the decline from the golden to the iron age. The sect of Stoicks adopted most fully the system of catastrophes destined at certain intervals to destroy the world. These they taught were of two kinds;—the Cataclysm, or destruction by deluge, which sweeps away the whole human race, and annihilates all the animal and vegetable productions of nature; and the Ecpyrosis, or conflagration, which dissolves the globe itself. From the Egyptians also they derived the doctrine of the gradual debasement of man from a state of innocence. Towards the termination of each era the gods could no longer bear with the wickedness of men, and a shock of the elements or a deluge overwhelmed them; after which calamity, Astrea again descended on the earth, to renew the golden age.†

* Prichard's Egypt. Mythol. p. 182.

† Ibid. p. 193.

The connection between the doctrine of successive catastrophes and repeated deteriorations in the moral character of the human race, is more intimate and natural than might at first be imagined. For, in a rude state of society, all great calamities are regarded by the people as judgments of God on the wickedness of man. Thus in our own time, the priests persuaded a large part of the population of Chili, and perhaps believed themselves, that the fatal earthquake of 1822 was a sign of the wrath of Heaven for the great political revolution just then consummated in South America. In like manner, in the account given to Solon by the Egyptian priests, of the submersion of the island of Atlantis under the waters of the ocean, after repeated shocks of an earthquake, we find that the event happened when Jupiter had seen the moral depravity of the inhabitants.* Now, when the notion had once gained ground, whether from causes before suggested or not, that the earth had been destroyed by several general catastrophes, it would next be inferred that the human race had been as often destroyed and renovated. And since every extermination was assumed to be penal, it could only be reconciled with divine justice, by the supposition that man, at each successive creation, was regenerated in a state of purity and innocence.

A very large portion of Asia, inhabited by the earliest nations whose traditions have come down to us, has been always subject to tremendous earthquakes. Of the geographical boundaries of these, and their effects, I shall speak in the proper place. Egypt has, for the most part, been exempt from this scourge, and

* Plato's *Timæus*.

the tradition of catastrophes in that country was perhaps derived from the East.

One extraordinary fiction of the Egyptian mythology was the supposed intervention of a masculo-feminine principle, to which was assigned the development of the embryo world, somewhat in the way of incubation. For the doctrine was, that when the first chaotic mass had been produced, in the form of an egg, by a self-dependent and eternal being, it required the mysterious functions of this masculo-feminine artificer to reduce the component elements into organized forms.

Although it is scarcely possible to recall to mind this conceit without smiling, it does not seem to differ essentially in principle from some cosmological notions of men of great genius and science in modern Europe. The Egyptian philosophers ventured on the perilous task of seeking from among the processes now going on something analogous to the mode of operation employed by the Author of Nature in the first creation of organized beings, and they compared it to that which governs the birth of new individuals by generation. To suppose that some general rules might be observed in the first origin of created beings, or the first introduction of new species into our system, was not absurd, nor inconsistent with any thing known to us in the economy of the universe. But the hypothesis, that there was any analogy between such laws and those employed in the continual reproduction of species, was purely gratuitous. In like manner, it is not unreasonable, nor derogatory to the attributes of Omnipotence, to imagine that some general laws may be observed in the creation of new worlds; and if man could witness the birth of such worlds, he might reason by induction upon the origin of his own. But in the

absence of such data, an attempt has been made to fancy some analogy between the agents now employed to destroy, renovate, and perpetually vary the earth's surface, and those whereby the first chaotic mass was formed, and brought by supposed nascent energy from the embryo to the habitable state.

By how many shades the elaborate systems, constructed on these principles, may differ from the mysteries of the "Mundane Egg" of Egyptian fable, I shall not inquire. It would, perhaps, be dangerous ground; and some of our contemporaries might not sit as patiently as the Athenian audience, when the fiction of the chaotic egg, engrafted by Orpheus upon their own mythology, was turned into ridicule by Aristophanes. That comedian introduced his birds singing, in a solemn hymn, "How sable-plumaged Night conceived in the boundless bosom of Erebus, and laid an egg, from which, in the revolution of ages, sprung Love, resplendent with golden pinions. Love fecundated the dark-winged chaos, and gave origin to the race of birds." *

Pythagorean Doctrines. — Pythagoras, who resided for more than twenty years in Egypt, and, according to Cicero, had visited the East, and conversed with the Persian philosophers, introduced into his own country, on his return, the doctrine of the gradual deterioration of the human race from an original state of virtue and happiness: but if we are to judge of his theory concerning the destruction and renovation of the earth from the sketch given by Ovid, we must concede it to have been far more philosophical than any known version of the cosmologies of oriental or Egyptian sects.

* Aristophanes, Birds, 694.

Although Pythagoras is introduced by the poet as delivering his doctrine in person, some of the illustrations are derived from natural events which happened after the death of the philosopher. But notwithstanding these anachronisms, we may regard the account as a true picture of the tenets of the Pythagorean school in the Augustan age; and although perhaps partially modified, it must have contained the substance of the original scheme. Thus considered, it is extremely curious and instructive; for we here find a comprehensive and masterly summary of almost all the great causes of change now in activity on the globe, and these adduced in confirmation of a principle of a perpetual and gradual revolution inherent in the nature of our terrestrial system. These doctrines, it is true, are not directly applied to the explanation of geological phenomena; or, in other words, no attempt is made to estimate what may have been in past ages, or what may hereafter be, the aggregate amount of change brought about by such never-ending fluctuations. Had this been the case, we might have been called upon to admire so extraordinary an anticipation with no less interest than astronomers, when they endeavour to divine by what means the Samian philosopher came to the knowledge of the Copernican system.

Let us now examine the celebrated passages to which we have been adverting *:—

“ Nothing perishes in this world; but things merely vary and change their form. To be born, means simply that a thing begins to be something different from what it was before; and dying, is ceasing to be the same thing. Yet, although nothing retains long the same

* Ovid's Metamor. lib. 15.

image, the sum of the whole remains constant." These general propositions are then confirmed by a series of examples, all derived from natural appearances, except the first, which refers to the golden age giving place to the age of iron. The illustrations are thus consecutively adduced.

1. Solid land has been converted into sea.
2. Sea has been changed into land. Marine shells lie far distant from the deep, and the anchor has been found on the summit of hills.
3. Valleys have been excavated by running water, and floods have washed down hills into the sea.*
4. Marshes have become dry ground.
5. Dry lands have been changed into stagnant pools.
6. During earthquakes some springs have been closed up, and new ones have broken out. Rivers have deserted their channels, and have been re-born elsewhere; as the Erasinus in Greece, and Mysus in Asia.
7. The waters of some rivers, formerly sweet, have become bitter, as those of the Anigris in Greece, &c.†
8. Islands have become connected with the main land by the growth of deltas and new deposits, as in the case of Antissa joined to Lesbos, Pharos to Egypt, &c.
9. Peninsulas have been divided from the main land, and have become islands, as Leucadia; and according to tradition Sicily, the sea having carried away the isthmus.

* *Eluvie mons est deductus in aquor*, v. 267. The meaning of this last verse is somewhat obscure, but, taken with the context, may be supposed to allude to the abrading power of floods, torrents, and rivers.

† The impregnation from new mineral springs, caused by earthquakes in volcanic countries, is, perhaps, here alluded to.

10. Land has been submerged by earthquakes: the Grecian cities of Helice and Buris, for example, are to be seen under the sea, with their walls inclined.

11. Plains have been upheaved into hills by the confined air seeking vent, as at Trœzen in the Peloponnesus.

12. The temperature of some springs varies at different periods. The waters of others are inflammable.*

13. There are streams which have a petrifying power, and convert the substances which they touch into marble.

14. Extraordinary medicinal and deleterious effects are produced by the water of different lakes and springs.†

15. Some rocks and islands, after floating and having been subject to violent movements, have at length become stationary and immoveable, as Delos, and the Cyanean Isles.‡

16. Volcanic vents shift their position; there was a time when Etna was not a burning mountain, and the time will come when it will cease to burn. Whether

* This is probably an allusion to the escape of inflammable gas, like that in the district of Baku, west of the Caspian; at Pietramala, in the Tuscan Apennines; and several other places.

† Many of those described seem fanciful fictions, like the virtues still so commonly attributed to mineral waters.

‡ Raspe, in a learned and judicious essay (*De Novis Insulis*, cap. 19.), has made it appear extremely probable that all the traditions of certain islands in the Mediterranean having at some former time frequently shifted their positions, and at length become stationary, originated in the great change produced in their form by earthquakes and submarine eruptions, of which there have been modern examples in the new islands raised in the time of history. When the series of convulsions ended, the island was said to become fixed.

it be that some caverns become closed up by the movements of the earth, and others opened, or whether the fuel is finally exhausted, &c. &c.

The various causes of change in the inanimate world having been thus enumerated, the doctrine of equivocal generation is next propounded, as illustrating a corresponding perpetual flux in the animate creation.*

In the Egyptian and Eastern cosmogonies, and in the Greek version of them, no very definite meaning can, in general, be attached to the term "destruction of the world;" for sometimes it would seem almost to imply the annihilation of our planetary system, and at others a mere revolution of the surface of the earth.

Opinions of Aristotle. — From the works now extant of Aristotle, and from the system of Pythagoras, as above exposed, we might certainly infer that these philosophers considered the agents of change now operating in nature, as capable of bringing about in the lapse of ages a complete revolution; and the Stagyrite even considers occasional catastrophes, hap-

* It is not inconsistent with the Hindoo mythology to suppose that Pythagoras might have found in the East not only the system of universal and violent catastrophes and periods of repose in endless succession, but also that of periodical revolutions, effected by the continued agency of ordinary causes. For Brahma, Vishnu, and Siva, the first, second, and third persons of the Hindoo triad, severally represented the Creative, the Preserving, and the Destroying powers of the Deity. The co-existence of these three attributes, all in simultaneous operation, might well accord with the notion of perpetual but partial alterations finally bringing about a complete change. But the fiction expressed in the verses before quoted from Menū, of eternal vicissitudes in the vigils and slumbers of the Infinite Being, seems accommodated to the system of great general catastrophes followed by new creations and periods of repose.

pening at distant intervals of time, as part of the regular and ordinary course of nature. The deluge of Deucalion, he says, affected Greece only, and principally the part called Hellas, and it arose from great inundations of rivers during a rainy winter. But such extraordinary winters, he says, though after a certain period they return, do not always revisit the same places.*

Censorinus quotes it as Aristotle's opinion, that there were general inundations of the globe, and that they alternated with conflagrations; and that the flood constituted the winter of the great year, or astronomical cycle, while the conflagration, or destruction by fire, is the summer or period of greatest heat.† If this passage, as Lipsius supposes, be an amplification, by Censorinus, of what is written in "the Meteorics," it is a gross misrepresentation of the doctrine of the Stagyrite, for the general bearing of his reasoning in that treatise tends clearly in an opposite direction. He refers to many examples of changes now constantly going on, and insists emphatically on the great results which they must produce in the lapse of ages. He instances particular cases of lakes that had dried up, and deserts that had at length become watered by rivers and fertilized. He points to the growth of the Nilotic delta since the time of Homer, to the shallowing of the Palus Maeotis within sixty years from his own time; and although, in the same chapter, he says nothing of earthquakes, yet in others of the same treatise he shows himself not unacquainted with their effects.‡ He alludes, for

* *Meteor.* lib. i. cap. 12.

† *De Die Nat.*

‡ Lib. ii. cap. 14, 15, and 16.

example, to the upheaving of one of the Eolian islands previous to a volcanic eruption. “The changes of the earth,” he says, “are so slow in comparison to the duration of our lives, that they are overlooked ($\lambda\alpha\tau\theta\alpha\nu\epsilon\tau$); and the migrations of people after great catastrophes, and their removal to other regions, cause the event to be forgotten.” *

When we consider the acquaintance displayed by Aristotle, in his various works, with the destroying and renovating powers of Nature, the introductory and concluding passages of the twelfth chapter of his “Meteorics” are certainly very remarkable. In the first sentence he says, “The distribution of land and sea in particular regions does not endure throughout all time, but it becomes sea in those parts where it was land, and again it becomes land where it was sea; and there is reason for thinking that these changes take place according to a certain system, and within a certain period.” The concluding observation is as follows : — “As time never fails, and the universe is eternal, neither the Tanais, nor the Nile, can have flowed for ever. The places where they rise were once dry, and there is a limit to their operations; but there is none to time. So also of all other rivers; they spring up, and they perish; and the sea also continually deserts some lands and invades others. The same tracts, therefore, of the earth are not, some always sea, and others always continents, but every thing changes in the course of time.”

It seems, then, that the Greeks had not only derived from preceding nations, but had also, in some slight degree, deduced from their own observations, the

* Lib. ii. cap. 14, 15, and 16.

theory of periodical revolutions in the inorganic world : there is, however, no ground for imagining that they contemplated former changes in the races of animals and plants. Even the fact that marine remains were inclosed in solid rocks, although observed by some, and even made the groundwork of geological speculation, never stimulated the industry or guided the inquiries of naturalists. It is not impossible that the theory of equivocal generation might have engendered some indifference on this subject, and that a belief in the spontaneous production of living beings from the earth or corrupt matter might have caused the organic world to appear so unstable and fluctuating, that phenomena indicative of former changes would not awaken intense curiosity. The Egyptians, it is true, had taught, and the Stoics had repeated, that the earth had once given birth to some monstrous animals, which existed no longer ; but the prevailing opinion seems to have been, that after each great catastrophe the same species of animals were created over again. This tenet is implied in a passage of Seneca, where, speaking of a future deluge, he says, " Every animal shall be generated anew, and man free from guilt shall be given to the earth."*

An old Arabian version of the doctrine of the successive revolutions of the globe, translated by Abraham Ecchellensis †, seems to form a singular exception to the general rule, for here we find the idea of different

* *Omne ex integro animal generabitur, dabiturque terris homo inscius scelerum.* — *Quæst. Nat.* iii. c. 29.

† This author was Regius Professor of Syriac and Arabic at Paris, where, in 1685, he published a Latin translation of many Arabian MSS. on different departments of philosophy. This work has always been considered of high authority.

genera and species having been created. The Gerbanites, a sect of astronomers who flourished some centuries before the Christian era, taught as follows:— “That after every period of thirty-six thousand four hundred and twenty-five years, there were produced a pair of *every* species of animal, both male and female, from whom animals might be propagated and inhabit this lower world. But when a circulation of the heavenly orbs was completed, which is finished in that space of years, *other genera and species* of animals are propagated, as also of plants and other things, and the first order is destroyed, and so it goes on for ever and ever.”*

Theory of Strabo.—As we learn much of the tenets of the Egyptian and oriental schools in the writings of the Greeks, so many speculations of the early Greek authors are made known to us in the works of the

* Gerbanitæ docebant singulos triginta sex mille annos quadragesimos, viginti quinque bina ex singulis animalium speciebus produci, marem scilicet ac feminam, ex quibus animalia propagantur, huncque inferiorem incolunt orbem. Absolutâ autem cœlestium orbium circulatione, quæ illo annorum conficitur spatio, iterum alia producuntur animalium genera et species, quemadmodum et plantarum aliarumque rerum, et primus destruitur ordo, sicque in infinitum producitur.—*Histor. Orient. Suppl.* per Abrahamum Ecchellensum, Syrum Maronitam, cap. 7. et 8. ad calcem Chronici Oriental. Parisiis, e Typ. regia, 1685, fol.

I have given the punctuation as in the Paris edition, there being no comma after *quinque*; but, at the suggestion of M. de Schlegel, I have referred the number twenty-five to the period of years, and not to the number of pairs of each species created at one time, as I had done in the two first editions. Fortis inferred that twenty-five new *species* only were created at a time; a construction which the passage will not admit. *Mém. sur l'Hist. Nat. de l'Italie*, vol. i. p. 202.

Augustan and later ages. Strabo, in particular, enters largely, in the second book of his Geography, into the opinions of Eratosthenes and other Greeks on one of the most difficult problems in geology, viz. by what causes marine shells came to be plentifully buried in the earth at such great elevations and distances from the sea.

He notices, amongst others, the explanation of Xanthus the Lydian, who said that the seas had once been more extensive, and that they had afterwards been partially dried up, as in his own time many lakes, rivers, and wells in Asia had failed during a season of drought. Treating this conjecture with merited disregard, Strabo passes on to the hypothesis of Strato, the natural philosopher, who had observed that the quantity of mud brought down by rivers into the Euxine was so great, that its bed must be gradually raised, while the rivers still continue to pour in an undiminished quantity of water. He, therefore, conceived that, originally, when the Euxine was an inland sea, its level had by this means become so much elevated that it burst its barrier near Byzantium, and formed a communication with the Propontis; and this partial drainage, he supposed, had already converted the left side into marshy ground, and thus, at last, the whole would be choked up with soil. So, it was argued, the Mediterranean had once opened a passage for itself by the Columns of Hercules into the Atlantic; and perhaps the abundance of sea-shells in Africa, near the Temple of Jupiter Ammon, might also be the deposit of some former inland sea, which had at length forced a passage and escaped.

But Strabo rejects this theory, as insufficient to account for all the phenomena, and he proposes one of his own, the profoundness of which modern geologists

are only beginning to appreciate. "It is not," he says, "because the lands covered by seas were originally at different altitudes, that the waters have risen, or subsided, or receded from some parts and inundated others. But the reason is, that the same land is sometimes raised up and sometimes depressed, and the sea also is simultaneously raised and depressed, so that it either overflows or returns into its own place again. We must, therefore, ascribe the cause to the ground, either to that ground which is under the sea, or to that which becomes flooded by it, but rather to that which lies beneath the sea, for this is more moveable, and, on account of its humidity, can be altered with greater celerity.* *It is proper*," he observes in continuation, "*to derive our explanations from things which are obvious, and in some measure of daily occurrence, such as deluges, earthquakes, and volcanic eruptions †, and sudden swellings of the land beneath the sea;* for the last raise up the sea also; and when the same lands subside again, they occasion the sea to be let down. And it is not merely the small, but the large islands also, and not merely the islands, but the continents,

* "Quod enim hoc attollitur aut subsidit, et vel inundat quædam loca, vel ab iis recedit, ejus rei causa non est, quod alia aliis sola humiliora sint aut altiora; sed quod idem solum modò attollitur modò deprimitur, simulque etiam modò attollitur modò deprimitur mare: itaque vel exundat vel in suum reddit locum."

Postea, p. 88. "Restat, ut causam adscribam solo, sive quod mari subest sive quod inundatur; potius tamen ei quod mari subest. Hoc enim modò est mobilius, et quod ob humiditatem celerius mutari possit." — Strabo, Geog. Edit. Almelov. Amst. 1707. lib. i.

† *Volcanic eruptions*, eruptiones flatuum, in the Latin translation, and in the original Greek, *αναφυσηματα*, gaseous eruptions? or *inflations* of land? — Ibid. p. 98.

which can be lifted up together with the sea ; and both large and small tracts may subside, for habitations and cities, like Bure, Bizona, and many others, have been engulfed by earthquakes."

In another place, this learned geographer, in alluding to the tradition that Sicily had been separated by a convulsion from Italy, remarks, that at present the land near the sea in those parts was rarely shaken by earthquakes, since there were now open orifices whereby fire and ignited matters, and waters escape ; but formerly, when the volcanos of Etna, the Lipari Islands, Ischia, and others, were closed up, the imprisoned fire and wind might have produced far more vehement movements.* The doctrine, therefore, that volcanos are safety valves, and that the subterranean convulsions are probably most violent when first the volcanic energy shifts itself to a new quarter, is not modern.

We learn from a passage in Strabo†, that it was a dogma of the Gaulish Druids that the universe was immortal, but destined to survive catastrophes both of fire and water. That this doctrine was communicated to them from the East, with much of their learning, cannot be doubted. Cæsar, it will be remembered, says that they made use of Greek letters in arithmetical computations.‡

Pliny.—This philosopher had no theoretical opinions of his own concerning changes of the earth's surface ; and in this department, as in others, he restricted himself to the task of a compiler, without reasoning on the facts stated by him, or attempting to digest them into regular order. But his enumeration of the new islands

* Strabo, lib. vi. p. 396.

† Book iv.

‡ L. vi. ch. xiii.

which had been formed in the Mediterranean, and of other convulsions, shows that the ancients had not been inattentive observers of the changes which had taken place within the memory of man.

Such, then, appear to have been the opinions entertained before the Christian era, concerning the past revolutions of our globe. Although no particular investigations had been made for the express purpose of interpreting the monuments of ancient changes, they were too obvious to be entirely disregarded; and the observation of the present course of nature presented too many proofs of alterations continually in progress on the earth to allow philosophers to believe that nature was in a state of rest, or that the surface had remained, and would continue to remain, unaltered. But they had never compared attentively the results of the destroying and reproductive operations of modern times with those of remote eras, nor had they ever entertained so much as a conjecture concerning the comparative antiquity of the human race, or of living species of animals and plants, with those belonging to former conditions of the organic world. They had studied the movements and positions of the heavenly bodies with laborious industry, and made some progress in investigating the animal, vegetable, and mineral kingdoms; but the ancient history of the globe was to them a sealed book, and, although written in characters of the most striking and imposing kind, they were unconscious even of its existence.

CHAPTER III.

HISTORY OF THE PROGRESS OF GEOLOGY — *continued.*

Arabian writers of the tenth century — Avicenna — Omar — Cosmogony of the Koran — Kazwini — Early Italian writers — Leonardo da Vinci — Fracastoro — Controversy as to the real nature of fossils — Attributed to the Mosaic deluge — Palissy — Steno — Scilla — Quirini — Boyle — Lister — Leibnitz — Hooke's Theory of Elevation by Earthquakes — Of lost species of animals — Ray — Physico-theological writers — Woodward's Diluvial Theory — Burnet — Whiston — Vallisneri — Lazzaro Moro — Generelli — Buffon — His theory condemned by the Sorbonne as unorthodox — His declaration — Targioni — Arduino — Michell — Catcott — Raspe — Fuchsel — Fortis — Testa — Whitehurst — Pallas — Saussure.

Arabian writers. — AFTER the decline of the Roman empire, the cultivation of physical science was first revived with some success by the Saracens, about the middle of the eighth century of our era. The works of the most eminent classic writers were purchased at great expense from the Christians, and translated into Arabic ; and Al Mamûn, son of the famous Harûn-al-Rashid, the contemporary of Charlemagne, received with marks of distinction, at his court at Bagdad, astronomers and men of learning from different countries. This caliph, and some of his successors, encountered much opposition and jealousy from the doctors of the Mahometan law, who wished the Moslems to confine their studies to the Koran, dreading the effects of the diffusion of a taste for the physical sciences.*

* Mod. Univ. Hist. vol. ii. chap. iv. section iii.

Avicenna. — Almost all the works of the early Arabian writers are lost. Amongst those of the tenth century, of which fragments are now extant, is a short treatise, “On the Formation and Classification of Minerals,” by Avicenna, a physician, in whose arrangement there is considerable merit. The second chapter, “On the Cause of Mountains,” is remarkable; for mountains, he says, are formed, some by essential, others by accidental causes. In illustration of the essential, he instances “a violent earthquake, by which land is elevated, and becomes a mountain;” of the accidental, the principal, he says, is excavation by water, whereby cavities are produced, and adjoining lands made to stand out and form eminences.*

Omar—Cosmogony of the Koran. — In the same century also, Omar, surnamed “El Aalem,” or “The Learned,” wrote a work on “The Retreat of the Sea.” It appears that on comparing the charts of his own time with those made by the Indian and Persian astronomers two thousand years before, he had satisfied himself that important changes had taken place since the times of history in the form of the coasts of Asia, and that the extension of the sea had been greater at some former periods. He was confirmed in this opinion by the numerous salt springs and marshes in the interior of Asia,—a phenomenon from which Pallas, in more recent times, has drawn the same inference.

Von Hoff has suggested, with great probability, that the changes in the level of the Caspian (some of which

* Montes quandoque fiunt ex causa essentiali, quandoque ex causa accidental. Ex essentiali causa, ut ex vehementi motu terrae elevatur terra, et fit mons. Accidental, &c. — De Congelatione Lapidum, ed. Gedani, 1682.

there is reason to believe have happened within the historical era), and the geological appearances in that district, indicating the desertion by that sea of its ancient bed, had probably led Omar to his theory of a general subsidence. But whatever may have been the proofs relied on, his system was declared contradictory to certain passages in the Koran, and he was called upon publicly to recant his errors ; to avoid which persecution he went into voluntary banishment from Samarkand.*

The cosmological opinions expressed in the Koran are few, and merely introduced incidentally : so that it is not easy to understand how they could have interfered so seriously with free discussion on the former changes of the globe. The Prophet declares that the earth was created in two days, and the mountains were then placed on it ; and during these, and two additional days, the inhabitants of the earth were formed ; and in two more the seven heavens.† There is no

* Von Hoff, *Geschichte der Veränderungen der Erdoberfläche*, vol. i. p. 406., who cites Delisle, *bey Hismann Welt- und Völker-geschichte*. *Alte Geschich.* 1^{er} theil, s. 294. — The Arabian persecutions for heretical dogmas in theology were often very sanguinary. In the same ages wherein learning was most in esteem, the Mahometans were divided into two sects, one of whom maintained that the Koran was increase, and had subsisted in the very essence of God from all eternity ; and the other, the Motazalites, who, admitting that the Koran was instituted by God, conceived it to have been first made when revealed to the Prophet at Mecca, and accused their opponents of believing in two eternal beings. The opinions of each of these sects were taken up by different caliphs in succession, and the followers of each sometimes submitted to be beheaded, or flogged till at the point of death, rather than renounce their creed. — *Mod. Univ. Hist.* vol. ii. ch. iv.

† Koran, chap. xli.

more detail of circumstances; and the deluge, which is also mentioned, is discussed with equal brevity. The waters are represented to have poured out of an oven; a strange fable, said to be borrowed from the Persian Magi, who represented them as issuing from the oven of an old woman.* All men were drowned, save Noah and his family; and then God said, “O earth, swallow up thy waters; and thou, O heaven, withhold thy rain;” and immediately the waters abated.†

We may suppose Omar to have represented the desertion of the land by the sea to have been gradual, and that his hypothesis required a greater lapse of ages than was consistent with Moslem orthodoxy; for it is to be inferred from the Koran, that man and this planet were created at the same time; and although Mahomet did not limit expressly the antiquity of the human race, yet he gave an implied sanction to the Mosaic chronology, by the veneration expressed by him for the Hebrew Patriarchs.‡

A manuscript work, entitled the “Wonders of Nature,” is preserved in the Royal Library at Paris, by an Arabian writer, Mohammed Kazwini, who flourished in the seventh century of the Hegira, or at the close of the thirteenth century of our era.§ Besides several curious remarks on aerolites, earthquakes, and the successive changes of position which the land and sea have undergone, we meet with the following beautiful passage, which is given as the narrative of

* Sale's Koran, chap. xi. see note.

† Ibid.

‡ Kossa, appointed master to the Caliph Al Mamûd, was author of a book, entitled “The History of the Patriarchs and Prophets, from the Creation of the World.” — Mod. Univ. Hist. vol. ii. ch. iv.

§ Translated by MM. Chezy and De Sacy, and cited by M. Elie de Beaumont, Ann. des Sci. Nat. 1832.

Kidhz, an allegorical personage :— “ I passed one day by a very ancient and wonderfully populous city, and asked one of its inhabitants how long it had been founded. ‘ It is indeed a mighty city,’ replied he, ‘ we know not how long it has existed, and our ancestors were on this subject as ignorant as ourselves.’ Five centuries afterwards, as I passed by the same place, I could not perceive the slightest vestige of the city. I demanded of a peasant, who was gathering herbs upon its former site, how long it had been destroyed. ‘ In sooth a strange question ! ’ replied he. ‘ The ground here has never been different from what you now behold it.’ — ‘ Was there not of old,’ said I, ‘ a splendid city here ? ’ — ‘ Never,’ answered he, ‘ so far as we have seen, and never did our fathers speak to us of any such.’ On my return there 500 years afterwards, *I found the sea in the same place*, and on its shores were a party of fishermen, of whom I inquired how long the land had been covered by the waters? ‘ Is this a question,’ said they, ‘ for a man like you ? this spot has always been what it is now.’ I again returned, 500 years afterwards, and the sea had disappeared ; I inquired of a man who stood alone upon the spot, how long ago this change had taken place, and he gave me the same answer as I had received before. Lastly, on coming back again after an equal lapse of time, I found there a flourishing city, more populous and more rich in beautiful buildings than the city I had seen the first time, and when I would fain have informed myself concerning its origin, the inhabitants answered me, ‘ Its rise is lost in remote antiquity : we are ignorant how long it has existed, and our fathers were on this subject as ignorant as ourselves.’ ”

Early Italian writers. — It was not till the earlier

part of the sixteenth century that geological phenomena began to attract the attention of the Christian nations. At that period a very animated controversy sprang up in Italy, concerning the true nature and origin of marine shells, and other organized fossils, found abundantly in the strata of the peninsula. The celebrated painter Leonardo da Vinci, who in his youth had planned and executed some navigable canals in the north of Italy, was one of the first who applied sound reasoning to these subjects. The mud of rivers, he said, had covered and penetrated into the interior of fossil shells at a time when these were still at the bottom of the sea near the coast. "They tell us that these shells were formed in the hills by the influence of the stars; but I ask where in the hills are the stars now forming shells of distinct ages and species? and how can the stars explain the origin of gravel, occurring at different heights, and composed of pebbles rounded as if by the motion of running water; or in what manner can such a cause account for the petrification in the same places of various leaves, sea-weeds, and marine crabs?" *

The excavations made in 1517, for repairing the city of Verona, brought to light a multitude of curious petrifications, and furnished matter for speculation to different authors, and among the rest to Fracastoro †, who declared his opinion, that fossil shells had all belonged to living animals, which had

* See Venturi's extracts from Da Vinci's MSS. now in Library of Institute of France. They are not mentioned by Brocchi, and my attention was first called to them by Mr. Hallem. L. da Vinci died A. D. 1519.

† Museum Calceol.—See Brocchi's Discourse on the Progress of the Study of Fossil Conchology in Italy, where some of the following notices on Italian writers will be found more at large.

formerly lived and multiplied where their exuviae are now found. He exposed the absurdity of having recourse to a certain "plastic force," which it was said had power to fashion stones into organic forms; and with no less cogent arguments, demonstrated the futility of attributing the situation of the shells in question to the Mosaic deluge, a theory obstinately defended by some. That inundation, he observed, was too transient, it consisted principally of fluviatile waters; and if it had transported shells to great distances, must have strewed them over the surface, not buried them at vast depths in the interior of mountains. His clear exposition of the evidence would have terminated the discussion for ever, if the passions of mankind had not been enlisted in the dispute; and even though doubts should for a time have remained in some minds, they would speedily have been removed by the fresh information obtained almost immediately afterwards, respecting the structure of fossil remains, and of their living analogues.

But the clear and philosophical views of Fracastoro were disregarded, and the talent and argumentative powers of the learned were doomed for three centuries to be wasted in the discussion of these two simple and preliminary questions: first, whether fossil remains had ever belonged to living creatures; and, secondly, whether, if this be admitted, all the phenomena could not be explained by the Noachian deluge. It had been the general belief of the Christian world down to the period now under consideration, that the origin of this planet was not more remote than a few thousand years; and that since the creation the deluge was the only great catastrophe by which considerable change had been wrought on the earth's surface. On

the other hand, the opinion was scarcely less general, that the final dissolution of our system was an event to be looked for at no distant period. The era, it is true, of the expected millennium had passed away ; and for five hundred years after the fatal hour, when the annihilation of the planet had been looked for, the monks remained in undisturbed enjoyment of rich grants of land bequeathed to them by pious donors, who, in the preamble of deeds beginning “ appropinquante mundi termino ” —— “ appropinquante magno judicii die,” left lasting monuments of the popular delusion.*

But although in the sixteenth century it had become necessary to interpret certain prophecies respecting the millennium more liberally, and to assign a more distant date to the future conflagration of the world, we find, in the speculations of the early geologists, perpetual allusion to such an approaching catastrophe ; while in all that regarded the antiquity of the earth, no modification whatever of the opinions of the dark ages had been effected. Considerable alarm was at first excited when the attempt was made to invalidate, by physical proofs, an article of faith so generally received ; but there was sufficient spirit of toleration and candour amongst the Italian ecclesiastics, to allow the subject to be canvassed with much freedom. They even entered warmly into the controversy themselves, often favouring different sides of the question ; and however much we may deplore the loss of time and labour devoted to the defence of untenable positions,

* In Sicily, in particular, the title-deeds of many valuable grants of land to the monasteries are headed by such preambles, composed by the testators about the period when the good King Roger was expelling the Saracens from that island.

it must be conceded, that they displayed far less polemic bitterness than certain writers who followed them “beyond the Alps,” two centuries and a half later.

CONTROVERSY AS TO THE REAL NATURE OF FOSSIL ORGANIC REMAINS.

Mattioli—*Fallopio*.—The system of scholastic disputation encouraged in the universities of the middle ages had unfortunately trained men to habits of indefinite argumentation; and they often preferred absurd and extravagant propositions, because greater skill was required to maintain them; the end and object of these intellectual combats being victory, and not truth. No theory could be so far-fetched or fantastical as not to attract some followers, provided it fell in with popular notions; and as cosmogonists were not at all restricted, in building their systems, to the agency of known causes, the opponents of Fracastoro met his arguments by feigning imaginary causes, which differed from each other rather in name than in substance. Andrea Mattioli, for instance, an eminent botanist, the illustrator of Dioscorides, embraced the notion of Agricola, a skilful German miner, that a certain “materia pinguis,” or “fatty matter,” set into fermentation by heat, gave birth to fossil organic shapes. Yet Mattioli had come to the conclusion, from his own observations, that porous bodies, such as bones and shells, might be converted into stone, as being permeable to what he termed the “lapidifying juice.” In like manner, Fallopio of Padua conceived that petrified shells were generated by fermentation in the spots where they are found, or that they had in some cases acquired their form from “the tumultuous movements of terrestrial exhalations.” Although

celebrated as a professor of anatomy, he taught that certain tusks of elephants dug up in his time in Apulia were mere earthy concretions ; and, consistently with these principles, he even went so far as to consider it probable, that the vases of Monte Testaceo at Rome were natural impressions stamped in the soil.* In the same spirit, Mercati, who published, in 1574, faithful figures of the fossil shells preserved by Pope Sixtus V. in the Museum of the Vatican, expressed an opinion that they were mere stones, which had assumed their peculiar configuration from the influence of the heavenly bodies ; and Olivi of Cremona, who described the fossil remains of a rich Museum at Verona, was satisfied with considering them as mere "sports of nature."

Some of the fanciful notions of those times were deemed less unreasonable, as being somewhat in harmony with the Aristotelian theory of spontaneous generation, then taught in all the schools.† For men who had been taught in early youth, that a large proportion of living animals and plants were formed from the fortuitous concourse of atoms, or had sprung from the corruption of organic matter, might easily persuade themselves, that organic shapes, often imperfectly preserved in the interior of solid rocks, owed their existence to causes equally obscure and mysterious.

Cardano, 1552. — But there were not wanting some who, during the progress of this century, expressed more sound and sober opinions. The title of a work of Cardano's, published in 1552, " De Subtilitate,"

* *De Fossilib.* pp. 109. and 176.

† Aristotle, *On Animals*, chapters 1. and 15.

(corresponding to what would now be called Transcendental Philosophy), would lead us to expect, in the chapter on minerals, many far-fetched theories characteristic of that age ; but, when treating of petrified shells, he decided that they clearly indicated the former sojourn of the sea upon the mountains.*

Cesalpino—Majoli, 1597.—Cesalpino, a celebrated botanist, conceived that fossil shells had been left on the land by the retiring sea, and had concreted into stone during the consolidation of the soil † ; and in the following year (1597), Simeone Majoli‡ went still farther ; and, coinciding for the most part with the views of Cesalpino, suggested that the shells and submarine matter of the Veronese, and other districts, might have been cast up upon the land by volcanic explosions, like those which gave rise, in 1538, to Monte Nuovo, near Puzzuoli. This hint seems to have been the first imperfect attempt to connect the position of fossil shells with the agency of volcanos, a system afterwards more fully developed by Hooke, Lazzaro Moro, Hutton, and other writers.

Two years afterwards, Imperati advocated the animal origin of fossilized shells, yet admitted that stones could vegetate by force of “an internal principle ;” and, as evidence of this, he referred to the teeth of fish, and spines of echini found petrified.§

Palissy, 1580.—Palissy, a French writer on “The Origin of Springs from Rain-water,” and of other scientific works, undertook, in 1580, to combat the notions of many of his contemporaries in Italy, that petrified shells had all been deposited by the universal

* Brocchi, Con. Foss. Subap. Disc. sui Progressi. vol. i. p. 57.

† De Metallicis.

‡ Dies Caniculares.

§ *Storia Naturale*.

deluge. “He was the first,” said Fontenelle, when, in the French Academy, he pronounced his eulogy, nearly a century and a half later, “who dared assert,” in Paris, that fossil remains of testacea and fish had once belonged to marine animals.

Fabio Colonna. — To enumerate the multitude of Italian writers, who advanced various hypotheses, all equally fantastical, in the early part of the seventeenth century, would be unprofitably tedious; but Fabio Colonna deserves to be distinguished; for, although he gave way to the dogma, that all fossil remains were to be referred to the Noachian deluge, he resisted the absurd theory of Stelluti, who taught that fossil wood and ammonites were mere clay, altered into such forms by sulphureous waters and subterranean heat; and he pointed out the different states of shells buried in the strata, distinguishing between, first, the mere mould or impression; secondly, the cast or nucleus; and, thirdly, the remains of the shell itself. He had also the merit of being the first to point out, that some of the fossils had belonged to marine, and some to terrestrial testacea.*

Steno, 1669. — But the most remarkable work of that period was published by Steno, a Dane, once professor of anatomy at Padua, and who afterwards resided many years at the court of the Grand Duke of Tuscany. His treatise bears the quaint title of “*De Solido intra Solidum naturaliter contento* (1669),” by which the author intended to express, “On Gems, Crystals, and organic Petrifications inclosed within solid Rocks.” This work attests the priority of the Italian school in geological research; exemplifying at the

* *Osserv. sugli Animali aquat. e terrest.* 1626.

same time the powerful obstacles opposed, in that age, to the general reception of enlarged views in the science. It was still a favourite dogma, that the fossil remains of shells and marine creatures were not of animal origin; an opinion adhered to by many from their extreme reluctance to believe, that the earth could have been inhabited by living beings before a great part of the existing mountains were formed. In reference to this controversy, Steno had dissected a shark recently taken from the Mediterranean, and had demonstrated that its teeth and bones were identical with many fossils found in Tuscany. He had also compared the shells discovered in the Italian strata with living species, pointed out their resemblance, and traced the various gradations from shells merely calcined, or which had only lost their animal gluten, to those pétrifactions in which there was a perfect substitution of stony matter. In his division of mineral masses, he insisted on the secondary origin of those deposits in which the spoils of animals, or fragments of older rocks were inclosed. He distinguished between marine formations and those of a fluviatile character, the last containing reeds, grasses, or the trunks and branches of trees. He argued in favour of the original horizontality of sedimentary deposits, attributing their present inclined and vertical position sometimes to the escape of subterranean vapours, heaving the crust of the earth from below upwards, and sometimes to the falling in of masses over-lying subterranean cavities.

He declared that he had obtained proof that Tuscany must successively have acquired six distinct configurations, having been twice covered by water, twice laid dry with a level, and twice with an irregular and uneven

surface.* He displayed great anxiety to reconcile his new views with Scripture, for which purpose he pointed to certain rocks as having been formed before the existence of animals and plants ; selecting unfortunately as examples certain formations of limestone and sand-stone in his own country, now known to contain, though sparingly, the remains of animals and plants,— strata which do not even rank as the oldest part of our secondary series. Steno suggested that Moses, when speaking of the loftiest mountains as having been covered by the deluge, meant merely the loftiest of the hills then existing, which may not have been very high. The diluvian waters, he supposed, may have issued from the interior of the earth into which they had retired, when in the beginning the land was separated from the sea. These, and other hypotheses on the same subject, are not calculated to enhance the value of the treatise, and could scarcely fail to detract from the authority of those opinions which were sound and legitimate deductions from fact and observation. They have served, nevertheless, as the germs of many popular theories of later times, and in an expanded form have been put forth as original inventions by some of our contemporaries.

Scilla, 1670.—*Scilla*, a Sicilian painter, published, in 1670, a treatise, in Latin, on the fossils of Calabria, illustrated by good engravings. This work proves the continued ascendancy of dogmas often refuted ; for we find the wit and eloquence of the author chiefly directed against the obstinate incredulity of naturalists as to the organic nature of fossil shells.† Like many

* Sex itaque distinctas Etruriæ facies agnoscimus, dum bis fluida, bis plana, et sicca, bis aspera fuerit, &c.

† *Scilla* quotes the remark of Cicero on the story that a stone in

eminent naturalists of his day, Scilla gave way to the popular persuasion, that all fossil shells were the effects and proofs of the Mosaic deluge. It may be doubted whether he was perfectly sincere, and some of his contemporaries who took the same course were certainly not so. But so eager were they to root out what they justly considered an absurd prejudice respecting the nature of organized fossils, that they seem to have been ready to make any concessions, in order to establish this preliminary point. Such a compromising policy was short-sighted, since it was to little purpose that the nature of the documents should at length be correctly understood, if men were to be prevented from deducing fair conclusions from them.

Diluvial Theory. — The theologians who now entered the field in Italy, Germany, France, and England, were innumerable; and henceforward, they who refused to subscribe to the position, that all marine organic remains were proofs of the Mosaic deluge, were exposed to the imputation of disbelieving the whole of the sacred writings. Scarcely any step had been made in approximating to sound theories since the time of Fracastoro, more than a hundred years having been lost, in writing down the dogma that organized fossils were mere sports of nature. An additional period of a century and a half was now destined to be consumed in exploding the hypothesis, that organized fossils had all been buried in the solid strata by the Noachian

Chios had been cleft open, and presented the head of Paniscus in relief: — “I believe,” said the orator, “that the figure bore some resemblance to Paniscus, but not such that you would have deemed it sculptured by Scopas; for chance never perfectly imitates the truth.”

flood. Never did a theoretical fallacy, in any branch of science, interfere more seriously with accurate observation and the systematic classification of facts. In recent times, we may attribute our rapid progress chiefly to the careful determination of the order of succession in mineral masses, by means of their different organic contents, and their regular superposition. But the old diluvialists were induced by their system to confound all the groups of strata together instead of discriminating, — to refer all appearances to one cause and to one brief period, not to a variety of causes acting throughout a long succession of epochs. They saw the phenomena only as they desired to see them, sometimes misrepresenting facts, and at other times deducing false conclusions from correct data. Under the influence of such prejudices, three centuries were of as little avail as a few years in our own times, when we are no longer required to propel the vessel against the force of an adverse current.

It may be well, therefore, to forewarn the reader, that in tracing the history of geology from the close of the seventeenth to the end of the eighteenth century, he must expect to be occupied with accounts of the retardation, as well as of the advance, of the science. It will be necessary to point out the frequent revival of exploded errors, and the relapse from sound to the most absurd opinions; and to dwell on futile reasoning and visionary hypothesis, because some of the most extravagant systems were invented or controverted by men of acknowledged talent. In short, a sketch of the progress of geology is the history of a constant and violent struggle between new opinions, and doctrines sanctioned by the implicit faith of many generations, and supposed to rest on scriptural authority. The

inquiry, therefore, although highly interesting to one who studies the philosophy of the human mind, is too often barren of instruction to him who searches for truths in physical science.

Quirini, 1676.—Quirini, in 1676 *, contended, in opposition to Scilla, that the diluvian waters could not have conveyed heavy bodies to the summit of mountains, since the agitation of the sea never (as Boyle had demonstrated) extended to great depths †; and still less could the testacea, as some pretended, have lived in these diluvian waters ; for “the duration of the flood was brief, and *the heavy rains must have destroyed the saltiness of the sea !*” He was the first writer who ventured to maintain that the universality of the Noachian cataclysm ought not to be insisted upon. As to the nature of petrified shells, he conceived that as earthy particles united in the sea to form the shells of mollusca, the same crystallizing process might be effected on the land ; and that, in the latter case, the germs of the animals might have been disseminated through the substance of the rocks, and afterwards developed by virtue of humidity. Visionary as was this doctrine, it gained many proselytes even amongst

* *De Testaceis fossilibus Mus. Septaliani.*

† The opinions of Boyle, alluded to by Quirini, were published a few years before, in a short article entitled “On the Bottom of the Sea.” From observations collected from the divers of the pearl fishery, Boyle inferred that, when the waves were six or seven feet high above the surface of the water, there were no signs of agitation at the depth of fifteen fathoms ; and that even during heavy gales of wind, the motion of the water was exceedingly diminished at the depth of twelve or fifteen feet. He had also learnt from some of his informants, that there were currents running in opposite directions at different depths.—Boyle’s Works, vol. iii. p. 110. London, 1744.

the more sober reasoners of Italy and Germany ; for it conceded that the position of fossil bodies could not be accounted for by the diluvial theory.

Plot—Lister, 1678.—In the mean time, the doctrine that fossil shells had never belonged to real animals maintained its ground in England, where the agitation of the question began at a much later period. Dr. Plot, in his “Natural History of Oxfordshire” (1677), attributed to a “plastic virtue latent in the earth” the origin of fossil shells and fishes ; and Lister, to his accurate account of British shells, in 1678, added the fossil species, under the appellation of *turbinate and bivalve stones*. “Either,” said he, “these were terriginous, or, if otherwise, the animals they so exactly represent *have become extinct*.” This writer appears to have been the first who was aware of the continuity over large districts of the principal groups of strata in the British series, and who proposed the construction of regular geological maps.*

Leibnitz, 1680.—The great mathematician Leibnitz published his “*Protogaea*” in 1680. He imagined this planet to have been originally a burning luminous mass, which ever since its creation has been undergoing refrigeration. When the outer crust had cooled down sufficiently to allow the vapours to be condensed, they fell, and formed a universal ocean, covering the loftiest mountains, and investing the whole globe. The crust, as it consolidated from a state of fusion, assumed a vesicular and cavernous structure ; and being rent in some places, allowed the water to rush into the subterranean hollows, whereby the level of the primeval ocean was lowered. The

* See Mr. Conybeare’s excellent Introduction to the “Outlines of the Geology of England and Wales,” p. 12.

breaking in of these vast caverns is supposed to have given rise to the dislocated and deranged position of the strata "which Steno had described," and the same disruptions communicated violent movements to the incumbent waters, whence great inundations ensued. The waters, after they had been thus agitated, deposited their sedimentary matter during intervals of quiescence, and hence the various stony and earthy strata. "We may recognize, therefore," says Leibnitz, "a double origin of primitive masses, the one by refrigeration from igneous fusion, the other by concretion from aqueous solution."* By the repetition of similar causes (the disruption of the crust and consequent floods), alternations of new strata were produced, until at length these causes were reduced to a condition of quiescent equilibrium, and a more permanent state of things was established.†

Hooke, 1688.—The "Posthumous Works of Robert Hooke, M.D.," well known as a great mathematician and natural philosopher, appeared in 1705, containing "A Discourse of Earthquakes," which, we are informed by his editor, was written in 1668, but revised at subsequent periods.‡ Hooke frequently refers to

* Unde jam duplex origo intelligitur primorum corporum, una, cum ab ignis fusione refrescerent, altera, cum reconcrescerent ex solutione aquarum.

† Redeunte mox simili causâ strata subinde alia aliis impone-rentur, et facies teneri adhuc orbis sæpius novata est. Donec quiescentibus causis, atque æquilibris, consistentior emerget rerum status. — For an able analysis of the views of Leibnitz, in his *Protogœa*, see Mr. Conybeare's Report to the Brit. Assoc. on the Progress of Geological Science, 1832.

‡ Between the year 1688 and his death, in 1703, he read several memoirs to the Royal Society, and delivered lectures on various subjects, relating to fossil remains and the effects of earthquakes.

the best Italian and English authors who wrote before his time on geological subjects; but there are no passages in his works implying that he participated in the enlarged views of Steno and Lister, or of his contemporary, Woodward, in regard to the geographical extent of certain groups of strata. His treatise, however, is the most philosophical production of that age, in regard to the causes of former changes in the organic and inorganic kingdoms of nature.

"However trivial a thing," he says, "a rotten shell may appear to some, yet these monuments of nature are more certain tokens of antiquity than coins or medals, since the best of those may be counterfeited or made by art and design, as may also books, manuscripts, and inscriptions, as all the learned are now sufficiently satisfied has often been actually practised," &c.; "and though it must be granted that it is very difficult to read them (the records of nature) and *to raise a chronology out of them*, and to state the intervals of the time wherein such or such catastrophes and mutations have happened, yet it is not impossible."*

Respecting the extinction of species, Hooke was aware that the fossil ammonites, nautili, and many other shells and fossil skeletons found in England, were of different species from any then known; but he doubted whether the species had become extinct, observing that the knowledge of naturalists of all the marine species, especially those inhabiting the deep sea, was very deficient. In some parts of his writings, however, he leans to the opinion that species had been lost; and in speculating on this subject, he even suggests that

* Posth. Works, Lecture, Feb. 29. 1688.

there might be some connection between the disappearance of certain kinds of animals and plants, and the changes wrought by earthquakes in former ages. Some species, he observes with great sagacity, are "*peculiar to certain places*, and not to be found elsewhere. If, then, such a place had been swallowed up, it is not improbable but that those animate beings may have been destroyed with it; and this may be true both of aërial and aquatic animals: for those animated bodies, whether vegetables or animals, which were naturally nourished or refreshed by the air, would be destroyed by the water," &c.* Turtles, he adds, and such large ammonites as are found in Portland, seem to have been the productions of hotter countries; and it is necessary to suppose that England once lay under the sea within the torrid zone! To explain this and similar phenomena, he indulges in a variety of speculations concerning changes in the position of the axis of the earth's rotation, "a shifting of the earth's centre of gravity, analogous to the revolutions of the magnetic pole," &c. None of these conjectures, however, are proposed dogmatically, but rather in the hope of promoting fresh inquiries and experiments.

In opposition to the prejudices of his age, we find him arguing against the idea that nature had formed fossil bodies "for no other end than to play the mimic in the mineral kingdom;"—maintaining that figured stones were "really the several bodies they represent, or the mouldings of them petrified," and "not as some have imagined, 'a lusus naturæ,' sporting herself in the needless formation of useless beings."†

* Posth. Works, p. 327.

† Posth. Works, Lecture, Feb. 15. 1688. Hooke explained, with considerable clearness, the different modes wherein organic

It was objected to Hooke, that his doctrine of the extinction of species derogated from the wisdom and power of the Omnipotent Creator; but he answered, that, as individuals die, there may be some termination to the duration of a species; and his opinions, he declared, were not repugnant to Holy Writ: for the Scriptures taught that our system was degenerating, and tending to its final dissolution; “and as, when that shall happen, all the species will be lost, why not some at one time and some at another?”*

But his principal object was to account for the manner in which shells had been conveyed into the higher parts of “the Alps, Apennines, and Pyrenean hills, and the interior of continents in general.” These and other appearances, he said, might have been brought about by earthquakes, “which have turned plains into mountains, and mountains into plains, seas into land, and land into seas, made rivers where there were none before, and swallowed up others that for-

substances may become lapidified; and, among other illustrations, he mentions some silicified palm-wood brought from Africa, on which M. de la Hire had read a memoir to the Royal Academy of France (June, 1692), wherein he had pointed out, not only the tubes running the length of the trunk, but the roots at one extremity. De la Hire, says Hooke, also treated of certain trees found petrified in “the river that passes by Bakan, in the kingdom of Ava, and which has for the space of ten leagues the virtue of petrifying wood.” It is an interesting fact, that the silicified wood of the Irawadi should have attracted attention more than one hundred years ago. Remarkable discoveries have been recently made there of fossil animals and vegetables, by Mr. Crawfurd and Dr. Wallich.—See Geol. Trans. vol. ii. part iii. p. 377. second series. De la Hire cites Father Duchatz, in the second volume of “Observations made in the Indies by the Jesuits.”

* Posth. Works, Lecture, May 29. 1689.

merly were, &c. &c.; and which, since the creation of the world, have wrought many great changes on the superficial parts of the earth, and have been the instruments of placing shells, bones, plants, fishes, and the like, in those places where, with much astonishment, we find them." * This doctrine, it is true, had been laid down in terms almost equally explicit by Strabo, to explain the occurrence of fossil shells in the interior of continents, and to that geographer, and other writers of antiquity, Hooke frequently refers; but the revival and development of the system was an important step in the progress of modern science.

Hooke enumerated all the examples known to him of subterranean disturbance, from "the sad catastrophe of Sodom and Gomorrah" down to the Chilian earthquake of 1646. The elevating of the bottom of the sea, the sinking and submersion of the land, and most of the inequalities of the earth's surface, might, he said, be accounted for by the agency of these subterranean causes. He mentions that the coast near Naples *was raised during the eruption of Monte Nuovo*; and that, in 1591, land rose in the island of St. Michael, during an eruption: and although it would be more difficult, he says, to prove, he does not doubt but that there had been as many earthquakes in the parts of the earth under the ocean, as in the parts of the dry land; in confirmation of which, he mentions the immeasurable depth of the sea near some volcanos. To attest the extent of simultaneous subterranean movements, he refers to an earthquake in the West Indies, in the year 1690, where the space of earth raised, or

* Posth. Works, p. 312.

"struck upwards," by the shock, exceeded, he affirms, the length of the Alps and the Pyrenees.

Hooke's diluvial theory.—As Hooke declared the favorite hypothesis of the day, "that marine fossil bodies were to be referred to Noah's flood," to be wholly untenable, he appears to have felt himself called upon to substitute a diluvial theory of his own, and thus he became involved in countless difficulties and contradictions. "During the great catastrophe," he said, "there might have been a changing of that part which was before dry land into sea by sinking, and of that which was sea into dry land by raising, and marine bodies might have been buried in sediment beneath the ocean, in the interval between the creation and the deluge."* Then follows a disquisition on the separation of the land from the waters, mentioned in Genesis; during which operation some places of the shell of the earth were forced outwards, and others pressed downwards or inwards, &c. His diluvial hypothesis very much resembled that of Steno, and was entirely opposed to the fundamental principles professed by him, that he would explain the former changes of the earth *in a more natural manner* than others had done. When, in despite of this declaration, he required a former "crisis of nature," and taught that earthquakes had become debilitated, and that the Alps, Andes, and other chains, had been lifted up in a few months, he was compelled to assume so rapid a rate of change, that his machinery appeared scarcely less extravagant than that of his most fanciful predecessors. For this reason, perhaps, his whole theory of earthquakes met with undeserved neglect.

* Posth. Works, p 410.

Ray, 1692.—One of his contemporaries, the celebrated naturalist, Ray, participated in the same desire to explain geological phenomena, by reference to causes less hypothetical than those usually resorted to.* In his essay on “Chaos and Creation,” he proposed a system, agreeing in its outline, and in many of its details, with that of Hooke; but his knowledge of natural history enabled him to elucidate the subject with various original observations. Earthquakes, he suggested, might have been the second causes employed at the creation, in separating the land from the waters, and in gathering the waters together into one place. He mentions, like Hooke, the earthquake of 1646, which had violently shaken the Andes for some hundreds of leagues, and made many alterations therein. In assigning a cause for the general deluge, he preferred a change in the earth’s centre of gravity to the introduction of earthquakes. Some unknown cause, he said, might have forced the subterranean waters outwards, as was, perhaps, indicated by “the breaking up of the fountains of the great deep.”

Ray was one of the first of our writers who enlarged upon the effects of running water upon the land, and of the encroachment of the sea upon the shores. So important did he consider the agency of these causes, that he saw in them an indication of the tendency of our system to its final dissolution; and he wondered why the earth did not proceed more rapidly towards a general submersion beneath the sea, when so much

* Ray’s Physico-theological Discourses were of somewhat later date than Hooke’s great work on earthquakes. He speaks of Hooke as one “whom for his learning and deep insight into the mysteries of nature he deservedly honoured.”—*On the Deluge*, chap. iv.

matter was carried down by rivers, or undermined in the sea-cliffs. We perceive clearly from his writings, that the gradual decline of our system, and its future consummation by fire, was held to be as necessary an article of faith by the orthodox, as was the recent origin of our planet. His discourses, like those of Hooke, are highly interesting, as attesting the familiar association in the minds of philosophers, in the age of Newton, of questions in physics and divinity. Ray gave an unequivocal proof of the sincerity of his mind, by sacrificing his preferment in the church, rather than take an oath against the Covenanters, which he could not reconcile with his conscience. His reputation, moreover, in the scientific world placed him high above the temptation of courting popularity, by pandering to the physico-theological taste of his age. It is, therefore, curious to meet with so many citations from the Christian fathers and prophets in his essays on physical science — to find him in one page proceeding, by the strict rules of induction, to explain the former changes of the globe, and in the next gravely entertaining the question, whether the sun and stars, and the whole heavens shall be annihilated, together with the earth, at the era of the grand conflagration.

Woodward, 1695.—Among the contemporaries of Hooke and Ray, Woodward, a professor of medicine, had acquired the most extensive information respecting the geological structure of the crust of the earth. He had examined many parts of the British strata with minute attention; and his systematic collection of specimens, bequeathed to the University of Cambridge, and still preserved there as arranged by him, shows how far he had advanced in ascertaining the order of superposition. From the great number of facts col-

lected by him, we might have expected his theoretical views to be more sound and enlarged than those of his contemporaries; but in his anxiety to accommodate all observed phenomena to the scriptural account of the Creation and Deluge, he arrived at most erroneous results. He conceived "the whole terrestrial globe to have been taken to pieces and dissolved at the flood, and the strata to have settled down from this promiscuous mass as any earthy sediment from a fluid."* In corroboration of these views, he insisted upon the fact, that "marine bodies are lodged in the strata according to the order of their gravity, the heavier shells in stone, the lighter in chalk, and so of the rest."† Ray immediately exposed the unfounded nature of this assertion, remarking truly, that fossil bodies "are often mingled, heavy with light, in the same stratum;" and he even went so far as to say, that Woodward "must have invented the phenomena for the sake of confirming his bold and strange hypothesis ‡"—a strong expression from the pen of a contemporary.

Burnet, 1690.—At the same time Burnet published his "Theory of the Earth."§ The title is most characteristic of the age,—"The Sacred Theory of the Earth; containing an Account of the Original of the Earth, and of all the general Changes which it hath already undergone, or is to undergo, till the Consumption of all Things." Even Milton had scarcely ventured in his poem to indulge his imagination so freely in painting scenes of the Creation and Deluge, Paradise and Chaos. He explained why the primeval

* *Essay towards a Natural History of the Earth, 1695. Preface.*

† *Ibid.*

‡ *Consequences of the Deluge, p. 165.*

§ First published in Latin between the years 1680 and 1690.

earth enjoyed a perpetual spring before the flood ! showed how the crust of the globe was fissured by "the sun's rays," so that it burst, and thus the diluvial waters were let loose from a supposed central abyss. Not satisfied with these themes, he derived from the books of the inspired writers, and even from heathen authorities, prophetic views of the future revolutions of the globe, gave a most terrific description of the general conflagration, and proved that a new heaven and a new earth will rise out of a *second chaos* — after which will follow the blessed millennium.

The reader should be informed, that, according to the opinion of many respectable writers of that age, there was good scriptural ground for presuming that the garden bestowed upon our first parents was not on the earth itself, but above the clouds, in the middle region between our planet and the moon. Burnet approaches with becoming gravity the discussion of so important a topic. He was willing to concede that the geographical position of Paradise was not in Mesopotamia, yet he maintained that it was upon the earth, and in the southern hemisphere, near the equinoctial line. Butler selected this conceit as a fair mark for his satire, when, amongst the numerous accomplishments of Hudibras, he says, —

" He knew the seat of Paradise,
Could tell in what degree it lies ;
And, as he was disposed, could prove it
Below the moon, or else above it."

Yet the same monarch, who is said never to have slept without Butler's poem under his pillow, was so great an admirer and patron of Burnet's book, that he ordered it to be translated from the Latin into English. The style of the "Sacred Theory" was eloquent, and the

book displayed powers of invention of no ordinary stamp. It was, in fact, a fine historical romance, as Buffon afterwards declared: but it was treated as a work of profound science in the time of its author, and was panegyrized by Addison in a Latin ode, while Steele praised it in the "Spectator." Towards the end of the last century, Warton, in his "Essay on Pope," discovered that Burnet united the faculty of *judgment* with powers of imagination.

Whiston, 1696. — Another production of the same school, and equally characteristic of the time, was that of Whiston, entitled, "A New Theory of the Earth; wherein the Creation of the World in Six Days, the Universal Deluge, and the General Conflagration, as laid down in the Holy Scriptures, are shown to be perfectly agreeable to Reason and Philosophy." He was at first a follower of Burnet; but his faith in the infallibility of that writer was shaken by the declared opinion of Newton, that there was every presumption in astronomy against any former change in the inclination of the earth's axis. This was a leading dogma in Burnet's system, though not original, for it was borrowed from an Italian, Alessandro degli Alessandri, who had suggested it in the beginning of the fifteenth century, to account for the former occupation of the present continents by the sea. La Place has since strengthened the arguments of Newton, against the probability of any former revolution of this kind.

The remarkable comet of 1680 was fresh in the memory of every one when Whiston first began his cosmological studies; and the principal novelty of his speculations consisted in attributing the deluge to the near approach to the earth of one of these erratic bodies. Having ascribed an increase of the waters to

this source, he adopted Woodward's theory, supposing all stratified deposits to have resulted from the "chaotic sediment of the flood." Whiston was one of the first who ventured to propose that the text of Genesis should be interpreted differently from its ordinary acceptation, so that the doctrine of the earth having existed long previous to the creation of man might no longer be regarded as unorthodox. He had the art to throw an air of plausibility over the most improbable parts of his theory, and seemed to be proceeding in the most sober manner, and by the aid of mathematical demonstration, to the establishment of his various propositions. Locke pronounced a panegyric on his theory, commending him for having explained so many wonderful and before inexplicable things. His book, as well as Burnet's, was attacked and refuted by Keill.* Like all who introduced purely hypothetical causes to account for natural phenomena, Whiston retarded the progress of truth, diverting men from the investigation of the laws of sublunary nature, and inducing them to waste time in speculations on the power of comets to drag the waters of the ocean over the land—on the condensation of the vapours of their tails into water, and other matters equally edifying.

Hutchinson, 1724. — John Hutchinson, who had been employed by Woodward in making his collection of fossils, published afterwards, in 1724, the first part of his "Moses's Principia," wherein he ridiculed Woodward's hypothesis. He and his numerous followers were accustomed to declaim loudly against human learning; and they maintained that the Hebrew Scriptures, when rightly translated, comprised a perfect

* An Examination of Dr. Burnet's Theory, &c. 2d ed. 1734.

system of natural philosophy, for which reason they objected to the Newtonian theory of gravitation.

Celsius. — Andrea Celsius, the Swedish astronomer, published about this time his remarks on the gradual diminution and sinking of the waters in the Baltic, to which I shall have occasion to advert more particularly in the second volume (ch. 17. book 2.).

Scheuchzer, 1708. — In Germany, in the mean time, Scheuchzer laboured to prove, in a work entitled “The Complaint of the Fishes” (1708), that the earth had been remodelled at the deluge. Pluche, also, in 1732, wrote to the same effect; while Holbach, in 1753, after considering the various attempts to refer all the ancient formations to the Noachian flood, exposed the inadequacy of this cause.

Italian Geologists — Vallisneri. — I return with pleasure to the geologists of Italy, who preceded, as has been already shown, the naturalists of other countries in their investigations into the ancient history of the earth, and who still maintained a decided pre-eminence. They refuted and ridiculed the physico-theological systems of Burnet, Whiston, and Woodward *; while Vallisneri †, in his comments on the Woodwardian theory, remarked how much the interests of religion, as well as those of sound philosophy, had suffered by perpetually mixing up the sacred writings with questions in physical science. The works of this author were rich in original observations. He at-

* Ramazzini even asserted, that the ideas of Burnet were mainly borrowed from a dialogue of one Patrizio; but Brocchi, after reading that dialogue, assures us, that there was scarcely any other correspondence between these systems, except that both were equally whimsical.

† Dei Corpi Marini, Lettere critiche, &c. 1721.

tempted the first general sketch of the marine deposits of Italy, their geographical extent, and most characteristic organic remains. In his treatise, "On the Origin of Springs," he explained their dependence on the order, and often on the dislocations, of the strata, and reasoned philosophically against the opinions of those who regarded the disordered state of the earth's crust as exhibiting signs of the wrath of God for the sins of man. He found himself under the necessity of contending, in his preliminary chapter, against St. Jerome, and four other principal interpreters of Scripture, besides several professors of divinity, "that springs did not flow by subterranean siphons and cavities from the sea upwards, losing their saltiness in the passage," for this theory had been made to rest on the infallible testimony of Holy Writ.

Although reluctant to generalize on the rich materials accumulated in his travels, Vallisneri had been so much struck with the remarkable continuity of the more recent marine strata, from one end of Italy to the other, that he came to the conclusion that the ocean formerly extended over the whole earth, and after abiding there for a long time, had gradually subsided. This opinion, however untenable, was a great step beyond Woodward's diluvian hypothesis, against which Vallisneri, and after him all the Tuscan geologists, uniformly contended, while it was warmly supported by the members of the Institute of Bologna.*

Among others of that day, Spada, a priest of Grezzana, in 1737, wrote to prove that the petrified marine bodies near Verona were not diluvian.† Mattani drew a similar inference from the shells of Volterra

* Brocchi, p. 28.

† Ibid. p. 33.

and other places : while Costantini, on the other hand, whose observations on the valley of the Brenta and other districts were not without value, undertook to vindicate the truth of the deluge, as also to prove that Italy had been peopled by the descendants of Japhet.*

Moro, 1740.—Lazzaro Moro, in his work (published in 1740) “On the Marine Bodies which are found in the Mountains †,” attempted to apply the theory of earthquakes, as expounded by Strabo, Pliny, and other ancient authors, with whom he was familiar, to the geological phenomena described by Vallisneri.‡ His attention was awakened to the elevating power of subterranean forces by a remarkable phenomenon which happened in his own time, and which had also been noticed by Vallisneri in his letters. A new island rose in 1707 from a deep part of the sea near Santorin in the Mediterranean, during continued shocks of an earthquake, and, increasing rapidly in size, grew in less than a month to be half a mile in circumference, and about twenty-five feet above high-water mark. It was soon afterwards covered by volcanic ejections, but, when first examined, it was found to be a white rock, bearing on its surface living oysters and crustacea. In order to ridicule the various theories then in vogue, Moro ingeniously supposes the arrival on this new island of a party of naturalists ignorant of

* Brocchi, p. 37.

† *Sui Crostacei ed altri Corpi Marini che si trovano sui Monti.*

‡ Moro does not cite the works of Hooke and Ray ; and although so many of his views were in accordance with theirs, he was probably ignorant of their writings, for they had not been translated. As he always refers to the Latin edition of Burnet, and a French translation of Woodward, we may presume that he did not read English.

its recent origin. One immediately points to the marine shells, as proofs of the universal deluge ; another argues that they demonstrate the former residence of the sea upon the mountains ; a third dismisses them as mere *sports of nature* ; while a fourth affirms, that they were born and nourished within the rock in ancient caverns, into which salt water had been raised in the shape of vapour by the action of subterranean heat.

Moro pointed with great judgment to the *faults* and dislocations of the strata described by Vallisneri, in the Alps and other chains, in confirmation of his doctrine, that the continents had been heaved up by subterranean movements. He objected, on solid grounds, to the hypothesis of Burnet and of Woodward; yet he ventured so far to disregard the protest of Vallisneri, as to undertake the adaptation of every part of his own system to the Mosaic account of the creation. On the third day, he said, the globe was every where covered to the same depth by fresh water ; and when it pleased the Supreme Being that the dry land should appear, volcanic explosions broke up the smooth and regular surface of the earth composed of primary rocks. These rose in mountain masses above the waves, and allowed melted metals and salts to ascend through fissures. The sea gradually acquired its saltiness from volcanic exhalations, and, while it became more circumscribed in area, increased in depth. Sand and ashes ejected by volcanos were regularly disposed along the bottom of the ocean, and formed the secondary strata, which in their turn were lifted up by earthquakes. We need not follow this author in tracing the progress of the creation of vegetables and animals on the other days of creation ; but,

upon the whole, it may be remarked, that few of the old cosmological theories had been conceived with so little violation of known analogies.

Generelli's illustrations of Moro, 1749. — The style of Moro was extremely prolix, and, like Hutton, who, at a later period, advanced many of the same views, he stood in need of an illustrator. The Scotch geologist was hardly more fortunate in the advocacy of Playfair, than was Moro in numbering amongst his admirers Cirillo Generelli, who, nine years afterwards, delivered at a sitting of Academicians at Cremona a spirited exposition of his theory. This learned Carmelite friar does not pretend to have been an original observer, but he had studied sufficiently to enable him to confirm the opinions of Moro by arguments from other writers; and his selection of the doctrines then best established is so judicious, that a brief abstract of them cannot fail to be acceptable, as illustrating the state of geology in Europe, and in Italy in particular, before the middle of the last century.

The bowels of the earth, says he, have carefully preserved the memorials of past events, and this truth the marine productions so frequent in the hills attest. From the reflections of Lazzaro Moro, we may assure ourselves that these are the effects of earthquakes in past times, which have changed vast spaces of sea into terra firma, and inhabited lands into seas. In this, more than in any other department of physics, are observations and experiments indispensable, and we must diligently consider facts. The land is known, wherever we make excavations, to be composed of different strata or soils placed one above the other, some of sand, some of rock, some of chalk, others of marl, coal, pumice, gypsum, lime, and the rest. These

ingredients are sometimes pure, and sometimes confusedly intermixed. Within are often imprisoned different marine fishes, like dried mummies, and more frequently shells, crustacea, corals, plants, &c., not only in Italy, but in France, Germany, England, Africa, Asia, and America; — sometimes in the lowest, sometimes in the loftiest, beds of the earth, some upon the mountains, some in deep mines, others near the sea, and others hundreds of miles distant from it. Woodward conjectured that these marine bodies might be found every where; but there are rocks in which none of them occur, as is sufficiently attested by Vallisneri and Marsilli. The remains of fossil animals consist chiefly of their more solid parts, and the most rocky strata must have been soft when such exuviae were inclosed in them. Vegetable productions are found in different states of maturity, indicating that they were imbedded in different seasons. Elephants, elks, and other terrestrial quadrupeds, have been found in England and elsewhere, in superficial strata, never covered by the sea. Alternations are rare, yet not without example, of marine strata, and those which contain marshy and terrestrial productions. Marine animals are arranged in the subterraneous beds with admirable order, in distinct groups, oysters here, dentalia or corals there, &c., as now, according to Marsilli *, on the shores of the Adriatic. We must abandon the doctrine, once so popular, which denies that organized fossils were derived from living beings, and we cannot account for their present position by the ancient theory of Strabo, nor by that of Leibnitz, nor by the universal deluge, as explained by Woodward

* *Saggio fisico intorno alla Storia del Mare*, part i. p. 24.

and others: "nor is it reasonable to call the Deity capriciously upon the stage, and to make him work miracles for the sake of confirming our preconceived hypotheses."— "I hold in utter abomination, most learned Academicians! those systems which are built with their foundations in the air, and cannot be propped up without a miracle; and I undertake, with the assistance of Moro, to explain to you how these marine animals were transported into the mountains by natural causes." *

A brief abstract then follows of Moro's theory, by which, says Generelli, we may explain all the phenomena, as Vallisneri so ardently desired, "*without violence, without fictions, without hypotheses, without miracles.*"† The Carmelite then proceeds to struggle against an obvious objection to Moro's system, considered as a method of explaining the revolutions of the earth, *naturally*. If earthquakes have been the agents of such mighty changes, how does it happen that their effects since the times of history have been so inconsiderable? This same difficulty had, as we have seen, presented itself to Hooke, half a century before, and forced him to resort to a former "crisis of nature:" but Generelli defended his position by showing how numerous were the accounts of eruptions and earthquakes, of new islands, and of elevations and subsidences of land, and yet how much greater a number of like events must have been unattested and unre-

* "Abbomino al sommo qualsivoglia sistema, che sia di pianta fabbricato in aria; massime quando è tale, che non possa sostenersi senza un miracolo," &c. — *De' Crostacei e di altre Produz. del Mare, &c.* 1749.

† "Senza violenze, senza finzioni, senza supposti, senza miracoli." *De' Crostacei e di altre Produz. del Mare, &c.* 1749.

corded during the last six thousand years. He also appealed to Vallisneri as an authority to prove that the mineral masses containing shells bore, upon the whole, but a small proportion to those rocks which were destitute of organic remains ; and the latter, says the learned monk, might have been created as they now exist, *in the beginning*.

Generelli then describes the continual waste of mountains and continents, by the action of rivers and torrents, and concludes with these eloquent and original observations : — “ Is it possible that this waste should have continued for six thousand, and *perhaps* a greater number of years, and that the mountains should remain so great, unless their ruins have been repaired ? Is it credible that the Author of Nature should have founded the world upon such laws, as that the dry land should for ever be growing smaller, and at last become wholly submerged beneath the waters ? Is it credible that, amid so many created things, the mountains alone should daily diminish in number and bulk, without there being any repair of their losses ? This would be contrary to that order of Providence which is seen to reign in all other things in the universe. Wherefore I deem it just to conclude, that the same cause which, in the beginning of time, raised mountains from the abyss, has down to the present day continued to produce others, in order to restore from time to time the losses of all such as sink down in different places, or are rent asunder, or in other way suffer disintegration. If this be admitted, we can easily understand why there should now be found upon many mountains so great a number of crustacea and other marine animals.”

In the above extract I have not merely enumerated

the opinions and facts which are confirmed by recent observation, suppressing all that has since proved to be erroneous, but have given a faithful abridgment of the entire treatise, with the omission only of Moro's hypothesis, which Generelli adopted, with all its faults and excellencies. The reader will therefore remark, that although this admirable essay embraces so large a portion of the principal objects of geological research, it makes no allusion to the extinction of certain classes of animals; and it is evident that no opinions on this head had, at that time, gained a firm footing in Italy. That Lister and other English naturalists should long before have declared in favour of the loss of species, while Scilla and most of his countrymen hesitated, was perhaps natural, since the Italian museums were filled with fossil shells belonging to species of which a great portion did actually exist in the Mediterranean; whereas the English collectors could obtain no recent species from such of their own strata as were then explored.

The weakest point in Moro's system consisted in deriving *all* the stratified rocks from volcanic ejections; an absurdity which his opponents took care to expose, especially Vito Amici.* Moro seems to have been misled by his anxious desire to represent the formation of secondary rocks as having occupied an extremely short period, while at the same time he wished to employ known agents in nature. To imagine torrents, rivers, currents, partial floods, and all the operations of moving water, to have gone on exerting an energy many thousand times greater than at present, would have appeared preposterous and incredible, and would

* *Sui Testacei della Sicilia.*

have required a hundred violent hypotheses; but we are so unacquainted with the true sources of subterranean disturbances, that their former violence may in theory be multiplied indefinitely, without its being possible to prove the same manifest contradiction or absurdity in the conjecture. For this reason, perhaps, Moro preferred to derive the materials of the strata from volcanic ejections, rather than from transportation by running water.

Marsilli.—Marsilli, whose work is alluded to by Generelli, had been prompted to institute inquiries into the bed of the Adriatic, by discovering, in the territory of Parma, (what Spada had observed near Verona, and Schiavo in Sicily,) that fossil shells were not scattered through the rocks at random, but disposed in regular order, according to certain genera and species.

Vitaliano Donati, 1750.—But with a view of throwing further light upon these questions, Donati, in 1750, undertook a more extensive investigation of the Adriatic, and discovered, by numerous soundings, that deposits of sand, marl, and tufaceous incrustations, most strictly analogous to those of the Subapennine hills, were in the act of accumulating there. He ascertained that there were no shells in some of the submarine tracts, while in other places they lived together in families, particularly the genera Arca, Pecten, Venus, Murex, and some others. He also states that in divers localities he found a mass composed of corals, shells, and crustaceous bodies of different species, confusedly blended with earth, sand, and gravel. At the depth of a foot or more, the organic substances were entirely petrified and reduced to marble; at less than a foot from the surface, they approached nearer to their na-

tural state; while at the surface they were alive, or if dead, in a good state of preservation.

Baldassari.—A contemporary naturalist, Baldassari, had shown that the organic remains in the tertiary marls of the Siennese territory were grouped in families, in a manner precisely similar to that above alluded to by Donati.

Buffon, 1749.—Buffon first made known his theoretical views concerning the former changes of the earth, in his Natural History, published in 1749. He adopted the theory of an original volcanic nucleus, together with the universal ocean of Leibnitz. By this aqueous envelope the highest mountains were once covered. Marine currents then acted violently, and formed horizontal strata, by washing away solid matter in some parts, and depositing it in others; they also excavated deep submarine valleys. The level of the ocean was then depressed by the entrance of a part of its waters into subterranean caverns, and thus some land was left dry. Buffon seems not to have profited, like Leibnitz and Moro, by the observations of Steno, or he could not have imagined that the strata were generally horizontal, and that those which contain organic remains had never been disturbed since the era of their formation. He was conscious of the great power annually exerted by rivers and marine currents in transporting earthy materials to lower levels, and he even contemplated the period when they would destroy all the present continents. Although in geology he was not an original observer, his genius enabled him to render his hypothesis attractive; and by the eloquence of his style, and the boldness of his speculations, he awakened curiosity, and provoked a spirit of inquiry amongst his countrymen.

Soon after the publication of his "Natural History," in which was included his "Theory of the Earth," he received an official letter (dated January, 1751,) from the Sorbonne, or Faculty of Theology in Paris, informing him that fourteen propositions in his works "were reprehensible, and contrary to the creed of the church." The first of these obnoxious passages, and the only one relating to geology, was as follows:—"The waters of the sea have produced the mountains and valleys of the land—the waters of the heavens, reducing all to a level, will at last deliver the whole land over to the sea, and the sea, successively prevailing over the land, will leave dry new continents like those which we inhabit." Buffon was invited by the College, in very courteous terms, to send in an explanation, or rather a recantation, of his unorthodox opinions. To this he submitted; and a general assembly of the Faculty having approved of his "Declaration," he was required to publish it in his next work. The document begins with these words:—"I declare that I had no intention to contradict the text of Scripture; that I believe most firmly all therein related about the creation, both as to order of time and matter of fact; and *I abandon every thing in my book respecting the formation of the earth*, and, generally, all which may be contrary to the narration of Moses." *

The grand principle which Buffon was called upon to renounce was simply this,—"that the present mountains and valleys of the earth are due to secondary causes, and that the same causes will in time destroy all the continents, hills, and valleys, and reproduce others like them." Now, whatever may be the defects of

* Hist. Nat. tom. v. éd. de l'Imp. Royale, Paris, 1769.

many of his views, it is no longer controverted that the present continents are of secondary origin. The doctrine is as firmly established as the earth's rotation on its axis ; and that the land now elevated above the level of the sea will not endure for ever, is an opinion which gains ground daily, in proportion as we enlarge our experience of the changes now in progress.

Targioni, 1751.—*Targioni*, in his voluminous “Travels in Tuscany, 1751 and 1754,” laboured to fill up the sketch of the geology of that region left by Steno sixty years before. Notwithstanding a want of arrangement and condensation in his memoirs, they contained a rich store of faithful observations. He has not indulged in many general views, but in regard to the origin of valleys, he was opposed to the theory of Buffon, who attributed them principally to submarine currents. The Tuscan naturalist laboured to show that both the larger and smaller valleys of the Apennines were excavated by rivers and floods, caused by the bursting of the barriers of lakes, after the retreat of the ocean. He also maintained that the elephants and other quadrupeds, so frequent in the lacustrine and alluvial deposits of Italy, had inhabited that peninsula ; and had not been transported thither, as some had conceived, by Hannibal or the Romans, nor by what they were pleased to term “a catastrophe of nature.”

Lehman, 1756.—In the year 1756 the treatise of *Lehman*, a German mineralogist, and director of the Prussian mines, appeared, who also divided mountains into three classes : the first, those formed with the world, and prior to the creation of animals, and which contained no fragments of other rocks ; the second class, those which resulted from the partial destruction

of the primary rocks by a general revolution; and a third class, resulting from local revolutions, and in part from the Noachian deluge.

A French translation of this work appeared in 1759, in the preface of which the translator displays very enlightened views respecting the operations of earthquakes, as well as of the aqueous causes.*

Gesner, 1758.—In this year Gesner, the botanist, of Zurich, published an excellent treatise on petrifactions, and the changes of the earth which they testify.† After a detailed enumeration of the various classes of fossils of the animal and vegetable kingdoms, and remarks on the different states in which they are found petrified, he considers the geological phenomena connected with them; observing, that some, like those of Oeningen, resembled the testacea, fish, and plants indigenous in the neighbouring region ‡; while some, such as ammonites, gryphites, belemnites, and other shells, are either of unknown species, or found only in the Indian and other distant seas. In order to elucidate the structure of the earth, he gives sections, from Verenius, Buffon, and others, obtained in digging wells; distinguishes between horizontal and inclined strata; and, in speculating on the causes of these appearances, mentions Donati's examination of the bed of the Adriatic; the filling up of lakes and seas by sediment; the imbedding of shells, now in progress; and many known effects of earthquakes, such as the sinking down of districts, or the heaving up of the bed of the sea, so as to form new islands and lay dry strata

* *Essai d'une Hist. Nat. des Couches de la Terre, 1759.*

† John Gesner published at Leyden, in Latin.

‡ Part ii. chap. 9.

containing petrifications. The ocean, he says, deserts its shores in many countries, as on the borders of the Baltic ; but the rate of recession has been so slow in the last 2000 years, that to allow the Apennines, whose summits are filled with marine shells, to emerge to their present height, would have required about 80,000 years,—a lapse of time ten times greater, or more, than the age of the universe. We must therefore refer the phenomenon to the command of the Deity, related by Moses, that “ the waters should be gathered together in one place, and the dry land appear.” Gesner adopted the views of Leibnitz, to account for the retreat of the primeval ocean : his essay displays much erudition ; and the opinions of preceding writers of Italy, Germany, and England are commented upon with fairness and discrimination.

Arduino, 1759.—In the year following, Arduino *, in his memoirs on the mountains of Padua, Vicenza, and Verona, deduced, from original observations, the distinction of rocks into primary, secondary, and tertiary, and showed that in those districts there had been a succession of submarine volcanic eruptions.

Michell, 1760.—In the following year (1760) the Rev. John Michell, Woodwardian Professor of Mineralogy at Cambridge, published in the *Philosophical Transactions*, an *Essay on the Cause and Phenomena of Earthquakes*.† His attention had been drawn to

* *Giornale del Griselini*, 1759.

† See a *Sketch of the History of English Geology*, by Dr. Fitton, in Edinb. Rev. Feb. 1818, re-edited Lond. and Edinb. Phil. Mag. vol. i. and ii. 1832–33. Some of Michell’s observations anticipate in so remarkable a manner the theories established forty years afterwards, that his writings would probably have formed an era in the science, if his researches had been uninterrupted. He held,

this subject by the great earthquake of Lisbon in 1755. He advanced many original and philosophical views respecting the propagation of subterranean movements, and the caverns and fissures wherein steam might be generated. In order to point out the application of his theory to the structure of the globe, he was led to describe the arrangement and disturbance of the strata, their usual horizontality in low countries, and their contortions and fractured state in the neighbourhood of mountain chains. He also explained, with surprising accuracy, the relations of the central ridges of older rocks to the “long narrow slips of similar earths, stones, and minerals,” which are parallel to these ridges. In his generalizations, derived in great part from his own observations on the geological structure of Yorkshire, he anticipated many of the views more fully developed by later naturalists.

Catcott, 1761.—Michell's papers were entirely free from all physico-theological disquisitions, but some of his contemporaries were still earnestly engaged in defending or impugning the Woodwardian hypothesis. We find many of these writings referred to by Catcott, an Hutchinsonian, who published a “Treatise on the Deluge” in 1761. He laboured particularly to refute an explanation offered by his contemporary, Bishop Clayton, of the Mosaic writings. That prelate had declared that the deluge “could not be literally true, save in respect to that part where Noah lived before the flood.” Catcott insisted on the universality of the

however, his professorship only eight years, when he succeeded to a benefice, and from that time he appears to have entirely discontinued his scientific pursuits.

deluge, and referred to traditions of inundations mentioned by ancient writers, or by travellers, in the East Indies, China, South America, and other countries. This part of his book is valuable, although it is not easy to see what bearing the traditions have, if admitted to be authentic, on the Bishop's argument, since no evidence is adduced to prove that the catastrophes were contemporaneous events, while some of them are expressly represented by ancient authors to have occurred in succession.

Fortis—Odoardi, 1761.—The doctrines of Arduino, above adverted to, were afterwards confirmed by Fortis and Desmarest, in their travels in the same country; and they, as well as Baldassari, laboured to complete the history of the Subapennine strata. In the work of Odoardi *, there was also a clear argument in favour of the distinct ages of the older Apennine strata, and the Subapennine formations of more recent origin. He pointed out that the strata of these two groups were *unconformable*, and must have been the deposits of different seas at distant periods of time.

Raspe, 1763.—A history of the new islands by Raspe, an Hanoverian, appeared in 1763, in Latin.† In this work, all the authentic accounts of earthquakes which had produced permanent changes on the solid parts of the earth were collected together and examined with judicious criticism. The best systems which had been proposed concerning the ancient history of the globe, both by ancient and modern

* *Sui Corpi Marini del Feltrino*, 1761.

† *De Novis e Mari Natis Insulis*. Raspe was also the editor of the “Philosophical Works of Leibnitz. Amst. et Leipzig, 1765;” also author of “Tassie’s Gems,” and “Baron Munchausen’s Travels.”

writers, are reviewed; and the merits and defects of the doctrines of Hooke, Ray, Moro, Buffon, and others, fairly estimated. Great admiration is expressed for the hypothesis of Hooke, and his explanation of the origin of the strata is shown to have been more correct than Moro's, while their theory of the effects of earthquakes was the same. Raspe had not seen Michell's memoirs, and his views concerning the geological structure of the earth were perhaps less enlarged; yet he was able to add many additional arguments in favour of Hooke's theory, and to render it, as he said, a nearer approach to what Hooke would have written had he lived in later times. As to the periods wherein all the earthquakes happened, to which we owe the elevation of various parts of our continents and islands, Raspe says he pretends not to assign their duration, still less to defend Hooke's suggestion, that the convulsions almost all took place during the deluge of Noah. He advertises to the apparent indications of the former tropical heat of the climate of Europe, and the changes in the species of animals and plants, as among the most obscure and difficult problems in geology. In regard to the islands raised from the sea, within the times of history or tradition, he declares that some of them were composed of strata containing organic remains, and that they were not, as Buffon had asserted, made of mere volcanic matter. His work concludes with an eloquent exhortation to naturalists to examine the isles which rose, in 1707, in the Grecian Archipelago, and, in 1720, in the Azores, and not to neglect such splendid opportunities of studying nature "in the act of parturition." That Hooke's writings should have been neglected for more than half a century, was matter of

astonishment to Raspe ; but it is still more wonderful that his own luminous exposition of that theory should, for more than another half century, have excited so little interest.

Fuchsel, 1762 and 1773.—*Fuchsel*, a German physician, published, in 1762, a geological description of the country between the Thuringerwald and the Hartz, and a memoir on the environs of Rudelstadt * ; and afterwards, in 1773, a theoretical work on the ancient history of the earth and of man.† He had evidently advanced considerably beyond his predecessor Lehman, and was aware of the distinctness, both as to position and fossil contents, of several groups of strata of different ages, corresponding to the secondary formations now recognized by geologists in various parts of Germany. He supposed the European continents to have remained covered by the sea until the formation of the marine strata called in Germany “muschelkalk,” at the same time that the terrestrial plants of many European deposits attested the existence of dry land which bordered the ancient sea ; land which, therefore, must have occupied the place of the present ocean. This pre-existing continent had been *gradually* swallowed up by the sea, different parts having subsided in succession into subterranean caverns. All the sedimentary strata were originally horizontal, and their present state of derangement must be referred to subsequent oscillations of the ground.

As there were plants and animals in the ancient periods, so also there must have been men, but they

* *Acta Academiae Electoralis Maguntinæ*, vol. ii. Erfurt.

† This account of *Fuchsel* is derived from an excellent analysis of his memoirs by M. Keferstein. *Journ. de Géologie*, tom. ii. Oct. 1830.

did not all descend from one pair, but were created at various points on the earth's surface ; and the number of these distinct birth-places was as great as are the original languages of nations.

In the writings of Fuchsel we see a strong desire manifested to explain geological phenomena as far as possible by reference to the agency of known causes ; and although some of his speculations were fanciful, his views coincide much more nearly with those now generally adopted, than the theories afterwards promulgated by Werner and his followers.

Brander, 1766.—Gustavus Brander published, in 1766, his "Fossilia Hantoniensia," containing excellent figures of fossil shells from the more modern marine strata of our island. "Various opinions," he says in the preface, "had been entertained concerning the time when and how these bodies became deposited. Some there are who conceive that it might have been effected in a wonderful length of time by a gradual changing and shifting of the sea," &c. But the most common cause assigned is that of "the deluge." This conjecture, he says, even if the universality of the flood be not called in question, is purely hypothetical. In his opinion, fossil animals and testacea were, for the most part, of unknown species ; and of such as were known, the living analogues now belonged to southern latitudes.

Soldani, 1780.—Soldani applied successfully his knowledge of zoology to illustrate the history of stratified masses. He explained that microscopic testacea and zoophytes inhabited the depths of the Mediterranean ; and that the fossil species were, in like manner, found in those deposits wherein the fineness of their particles, and the absence of pebbles, implied that they

were accumulated in a deep sea, or far from shore. This author first remarked the alternation of marine and fresh-water strata in the Paris basin.*

Fortis — Testa, 1793.—A lively controversy arose between Fortis and another Italian naturalist, Testa, concerning the fish of Monte Bolca, in 1793. Their letters †, written with great spirit and elegance, show that they were aware that a large proportion of the Subapennine shells were identical with living species, and some of them with species now living in the torrid zone. Fortis proposed a somewhat fanciful conjecture, that when the volcanos of the Vicentin were burning, the waters of the Adriatic had a higher temperature; and in this manner, he said, the shells of warmer regions may once have peopled their own seas. But Testa was disposed to think that these species of testacea were still common to their own and to equinoctial seas: for many, he said, once supposed to be confined to hotter regions, had been afterwards discovered in the Mediterranean.‡

Cortesi — Spallanzani — Wallerius — Whitehurst.— While these Italian naturalists, together with Cortesi

* *Saggio orittografico, &c.* 1780, and other Works.

† *Lett. sui Pesci Fossili di Bolca.* Milan, 1793.

‡ This argument of Testa has been strengthened of late years by the discovery, that dealers in shells had long been in the habit of selling Mediterranean species as shells of more southern and distant latitudes, for the sake of enhancing their price. It appears, moreover, from several hundred experiments made by that distinguished hydrographer, Captain Smyth, on the water within eight fathoms of the surface, that the temperature of the Mediterranean is on an average $3\frac{1}{2}^{\circ}$ of Fahrenheit higher than the western part of the Atlantic ocean; an important fact, which in some degree may help to explain why many species are common to tropical latitudes and to the Mediterranean.

and Spallanzani, were busily engaged in pointing out the analogy between the deposits of modern and ancient seas, and the habits and arrangement of their organic inhabitants, and while some progress was making, in the same country, in investigating the ancient and modern volcanic rocks, some of the most original observers among the English and German writers, Whitehurst * and Wallerius, were wasting their strength in contending, according to the old Woodwardian hypothesis, that all the strata were formed by the Noachian deluge. But Whitehurst's description of the rocks of Derbyshire was most faithful; and he atoned for false theoretical views, by providing data for their refutation.

Pallas — Saussure. — Towards the close of the eighteenth century, the idea of distinguishing the mineral masses on our globe into separate groups, and studying their relations, began to be generally diffused. Pallas and Saussure were among the most celebrated whose labours contributed to this end. After an attentive examination of the two great mountain chains of Siberia, Pallas announced the result, that the granitic rocks were in the middle, the schistose at their sides, and the limestones again on the outside of these; and this he conceived would prove a general law in the formation of all chains composed chiefly of primary rocks.†

In his “Travels in Russia,” in 1793 and 1794, he made many geological observations on the recent strata near the Wolga and the Caspian, and adduced

* Inquiry into the Original State and Formation of the Earth, 1778.

† Observ. on the Formation of Mountains. Act. Petrop. ann. 1778, part i.

proofs of the greater extent of the latter sea at no distant era in the earth's history. His memoir on the fossil bones of Siberia attracted attention to some of the most remarkable phenomena in geology. He stated that he had found a rhinoceros entire in the frozen soil, with its skin and flesh : an elephant, found afterwards in a mass of ice on the shore of the North Sea removed all doubt as to the accuracy of so wonderful a discovery.*

The subjects relating to natural history which engaged the attention of Pallas, were too multifarious to admit of his devoting a large share of his labours exclusively to geology. Saussure, on the other hand, employed the chief portion of his time in studying the structure of the Alps and Jura, and he provided valuable data for those who followed him. He did not pretend to deduce any general system from his numerous and interesting observations ; and the few theoretical opinions which escaped from him, seem, like those of Pallas, to have been chiefly derived from the cosmological speculations of preceding writers.

* Nov. comm. Petr. XVII. Cuvier, *Eloge de Pallas.*

CHAPTER IV.

HISTORY OF THE PROGRESS OF GEOLOGY — *continued.*

Werner's application of geology to the art of mining — Excessive character of his lectures — Enthusiasm of his pupils — His authority — His theoretical errors — Desmarest's Map and Description of Auvergne — Controversy between the Vulcanists and Neptunists — Intemperance of the rival sects — Hutton's Theory of the Earth — His discovery of granite veins — Originality of his views — Why opposed — Playfair's illustrations — Influence of Voltaire's writings on geology — Imputations cast on the Huttonians by Williams, Kirwan, and De Luc — Smith's Map of England — Geological Society of London — Progress of the science in France — Growing importance of the study of organic remains.

Werner. — The art of mining has long been taught in France, Germany, and Hungary, in scientific institutions established for that purpose, where mineralogy has always been a principal branch of instruction.*

Werner was named, in 1775, professor of that science in the "School of Mines," at Freyberg, in Saxony. He directed his attention not merely to the composition and external characters of minerals, but also to what he termed "geognosy," or the natural position of

* Our miners have been left to themselves, almost without the assistance of scientific works in the English language, and without any "school of mines," to blunder their own way into a certain degree of practical skill. The inconvenience of this want of system in a country where so much capital is expended, and often wasted, in mining adventures, has been well exposed by an eminent practical miner. — See "Prospectus of a School of Mines in Cornwall, by J. Taylor, 1825."

minerals in particular rocks, together with the grouping of those rocks, their geographical distribution, and various relations. The phenomena observed in the structure of the globe had hitherto served for little else than to furnish interesting topics for philosophical discussion : but when Werner pointed out their application to the practical purposes of mining, they were instantly regarded by a large class of men as an essential part of their professional education, and from that time the science was cultivated in Europe more ardently and systematically. Werner's mind was at once imaginative and richly stored with miscellaneous knowledge. He associated every thing with his favourite science, and in his excursive lectures he pointed out all the economical uses of minerals, and their application to medicine : the influence of the mineral composition of rocks upon the soil, and of the soil upon the resources, wealth, and civilization of man. The vast sandy plains of Tartary and Africa, he would say, retained their inhabitants in the shape of wandering shepherds ; the granitic mountains and the low calcareous and alluvial plains gave rise to different manners, degrees of wealth, and intelligence. The history even of languages, and the migrations of tribes, had been determined by the direction of particular strata. The qualities of certain stones used in building would lead him to descant on the architecture of different ages and nations ; and the physical geography of a country frequently invited him to treat of military tactics. The charm of his manners and his eloquence kindled enthusiasm in the minds of his pupils ; and many, who had intended at first only to acquire a slight knowledge of mineralogy, when they had once heard him, devoted themselves to it as the business of

their lives. In a few years, a small school of mines, before unheard of in Europe, was raised to the rank of a great university; and men already distinguished in science studied the German language, and came from the most distant countries to hear the great oracle of geology.*

Werner had a great antipathy to the mechanical labour of writing, and, with the exception of a valuable treatise on metalliferous veins, he could never be persuaded to pen more than a few brief memoirs, and those containing no development of his general views. Although the natural modesty of his disposition was excessive, approaching even to timidity, he indulged in the most bold and sweeping generalizations, and he inspired all his scholars with a most implicit faith in his doctrines. Their admiration of his genius, and the feelings of gratitude and friendship which they all felt for him, were not undeserved; but the supreme authority usurped by him over the opinions of his contemporaries was eventually prejudicial to the progress of the science; so much so, as greatly to counterbalance the advantages which it derived from his exertions. If it be true that delivery be the first, second, and third requisite in a popular orator, it is no less certain that to travel is of first, second, and third importance to those who desire to originate just and comprehensive views concerning the structure of our globe. Now Werner had not travelled to distant countries; he had merely explored a small portion of Germany, and conceived, and persuaded others to believe, that the whole surface of our planet, and all the mountain chains in the world, were made after the

* Cuvier, *Eloge de Werner.*

model of his own province. It became a ruling object of ambition in the minds of his pupils to confirm the generalizations of their great master, and to discover in the most distant parts of the globe his "universal formations," which he supposed had been each in succession simultaneously precipitated over the whole earth from a common menstruum, or "chaotic fluid." It now appears that the Saxon professor had misinterpreted many of the most important appearances even in the immediate neighbourhood of Freyberg. Thus, for example, within a day's journey of his school, the porphyry, called by him primitive, has been found not only to send forth veins or dikes through strata of the coal formation, but to overlie them in mass. The granite of the Hartz mountains, on the other hand, which he supposed to be the nucleus of the chain, is now well known to traverse the other beds, as near Goslar; and still nearer Freyberg, in the Erzgebirge, the mica slate does not mantle round the granite as was supposed, but abuts abruptly against it. Fragments, also, of the greywacké slate, containing organic remains, have recently been found entangled in the granite of the Hartz, by M. de Seckendorf.*

The principal merit of Werner's system of instruction consisted in steadily directing the attention of his scholars to the constant relations of superposition of certain mineral groups; but he had been anticipated, as has been shown in the last chapter, in the discovery of this general law, by several geologists in Italy and elsewhere; and his leading divisions of

* I am indebted for this information partly to Messrs. Sedgwick and Murchison, who have investigated the country, and partly to Dr. Charles Hartmann, the translator of this work into German.

the secondary strata were, at the same time, and independently, made the basis of an arrangement of the British strata by our countryman, William Smith, to whose work I shall presently return.

Controversy between the Vulcanists and Neptunists.—In regard to basalt and other igneous rocks, Werner's theory was original, but it was also extremely erroneous. The basalts of Saxony and Hesse, to which his observations were chiefly confined, consisted of tabular masses capping the hills, and not connected with the levels of existing valleys, like many in Auvergne and the Vivarais. These basalts, and all other rocks of the same family in other countries, were, according to him, chemical precipitates from water. He denied that they were the products of submarine volcanos ; and even taught that, in the primeval ages of the world, there were no volcanos. His theory was opposed, in a twofold sense, to the doctrine of the permanent agency of the same causes in nature ; for not only did he introduce, without scruple, many imaginary causes supposed to have once effected great revolutions in the earth, and then to have become extinct, but new ones also were feigned to have come into play in modern times ; and, above all, that most violent instrument of change, the agency of subterranean fire.

So early as 1768, before Werner had commenced his mineralogical studies, Raspe had truly characterized the basalts of Hesse as of igneous origin. Arduino, we have seen, had pointed out numerous varieties of trap-rock in the Vicentin as analogous to volcanic products, and as distinctly referable to ancient submarine eruptions. Desmarest, as before stated, had, in company with Fortis, examined the

Vicentin in 1766, and confirmed Arduino's views. In 1772, Banks, Solander, and Troil compared the columnar basalt of Hecla with that of the Hebrides. Collini, in 1774, recognized the true nature of the igneous rocks on the Rhine, between Andernach and Bonn. In 1775, Guettard visited the Vivaraïs, and established the relation of basaltic currents to lavas. Lastly, in 1779, Faujas published his description of the volcanos of the Vivaraïs and Velay, and showed how the streams of basalt had poured out from craters which still remain in a perfect state.*

Desmarest. — When sound opinions had thus for twenty years prevailed in Europe concerning the true nature of the ancient trap-rocks, Werner by his simple dictum caused a retrograde movement, and not only overturned the true theory, but substituted for it one of the most unphilosophical that can well be imagined. The continued ascendancy of his dogmas on this subject was the more astonishing, because a variety of new and striking facts were daily accumulated in favour of the correct opinions previously entertained. Desmarest, after a careful examination of Auvergne, pointed out, first, the most recent volcanos which had their craters still entire, and their streams of lava conforming to the level of the present river-courses. He then showed that there were others of an intermediate epoch, whose craters were nearly effaced, and whose lavas were less intimately connected with the present valleys; and, lastly, that there were volcanic rocks, still more ancient, without any discernible craters or scoriae, and bearing the closest analogy to rocks in

* Cuvier, *Eloge de Desmarest.*

other parts of Europe, the igneous origin of which was denied by the school of Freyberg.*

Desmarest's map of Auvergne was a work of uncommon merit. He first made a trigonometrical survey of the district, and delineated its physical geography with minute accuracy and admirable graphic power. He contrived, at the same time, to express, without the aid of colours, a vast quantity of geological detail, the different ages, and sometimes even the structure, of the volcanic rocks, distinguishing them from the fresh-water and the granitic. They alone who have carefully studied Auvergne, and traced the different lava-streams from their craters to their termination,—the various isolated basaltic cappings,—the relation of some lavas to the present valleys,—the absence of such relations in others,—can appreciate the extraordinary fidelity of this elaborate work. No other district of equal dimensions in Europe exhibits, perhaps, so beautiful and varied a series of phenomena; and, fortunately, Desmarest possessed at once the mathematical knowledge required for the construction of a map, skill in mineralogy, and a power of original generalization.

Dolomieu—Montlosier.—Dolomieu, another of Werner's contemporaries, had found prismatic basalt among the ancient lavas of Etna; and, in 1784, had observed the alternations of submarine lavas and calcareous strata in the Val di Noto, in Sicily. † In 1790, also, he described similar phenomena in the Vicentin and in the Tyrol. ‡ Montlosier published, in 1788, an essay on

* Journ. de Phys. vol. xiii. p. 115.; and Mém. de l'Inst., Sciences Mathémat. et Phys. vol. vi. p. 219.

† Journ. de Phys. tom. xxv. p. 191.

‡ Ib. tom. xxxvii. part. ii. p. 200.

the theory of the volcanos of Auvergne, combining accurate local observations with comprehensive views. Notwithstanding this mass of evidence, the scholars of Werner were prepared to support his opinions to their utmost extent; maintaining, in the fulness of their faith, that even obsidian was an aqueous precipitate. As they were blinded by their veneration for the great teacher, they were impatient of opposition, and soon imbibed the spirit of a faction; and their opponents, the Vulcanists, were not long in becoming contaminated with the same intemperate zeal. Ridicule and irony were weapons more frequently employed than argument by the rival sects, till at last the controversy was carried on with a degree of bitterness almost unprecedented in questions of physical science. Desmarest alone, who had long before provided ample materials for refuting such a theory, kept aloof from the strife; and whenever a zealous Neptunist wished to draw the old man into an argument, he was satisfied with replying, “Go and see.” *

Hutton, 1788.—It would be contrary to all analogy, in matters of graver import, that a war should rage with such fury on the Continent, and that the inhabitants of our island should not mingle in the affray. Although in England the personal influence of Werner was wanting to stimulate men to the defence of the weaker side of the question, they contrived to find good reason for espousing the Wernerian errors with great enthusiasm. In order to explain the peculiar motives which led many to enter, even with party feeling, into this contest, it will be necessary to present the reader with a sketch of the views unfolded by

* Cuvier, *Eloge de Desmarest.*

Hutton, a contemporary of the Saxon geologist. The former naturalist had been educated as a physician, but, declining the practice of medicine, he resolved, when young, to remain content with the small independence inherited from his father, and thenceforth to give his undivided attention to scientific pursuits. He resided at Edinburgh, where he enjoyed the society of many men of high attainments, who loved him for the simplicity of his manners and the sincerity of his character. His application was unwearied; and he made frequent tours through different parts of England and Scotland, acquiring considerable skill as a mineralogist, and constantly arriving at grand and comprehensive views in geology. He communicated the results of his observations unreservedly, and with the fearless spirit of one who was conscious that love of truth was the sole stimulus of his exertions. When at length he had matured his views, he published, in 1788, his "Theory of the Earth,"* and the same, afterwards more fully developed in a separate work, in 1795. This treatise was the first in which geology was declared to be in no way concerned about "questions as to the origin of things;" the first in which an attempt was made to dispense entirely with all hypothetical causes, and to explain the former changes of the earth's crust by reference exclusively to natural agents. Hutton laboured to give fixed principles to geology, as Newton had succeeded in doing to astronomy; but, in the former science, too little progress had been made towards furnishing the necessary data, to enable any philosopher, however great his genius, to realize so noble a project.

* Ed. Phil. Trans. 1788.

Huttonian theory. — “The ruins of an older world,” said Hutton, “are visible in the present structure of our planet; and the strata which now compose our continents have been once beneath the sea, and were formed out of the waste of pre-existing continents. The same forces are still destroying, by chemical decomposition or mechanical violence, even the hardest rocks, and transporting the materials to the sea, where they are spread out, and form strata analogous to those of more ancient date. Although loosely deposited along the bottom of the ocean, they become afterwards altered and consolidated by volcanic heat, and then heaved up, fractured, and contorted.”

Although Hutton had never explored any region of active volcanos, he had convinced himself that basalt and many other trap-rocks were of igneous origin, and that many of them had been injected in a melted state through fissures in the older strata. The compactness of these rocks, and their different aspect from that of ordinary lava, he attributed to their having cooled down under the pressure of the sea; and in order to remove the objections started against this theory, his friend, Sir James Hall, instituted a most curious and instructive series of chemical experiments, illustrating the crystalline arrangement and texture assumed by melted matter cooled under high pressure.

The absence of stratification in granite, and its analogy, in mineral character, to rocks which he deemed of igneous origin, led Hutton to conclude that granite also must have been formed from matter in fusion; and this inference he felt could not be fully confirmed, unless he discovered at the contact of granite and other strata a repetition of the phenomena exhibited so constantly by the trap-rocks. Resolved to try his

theory by this test, he went to the Grampians, and surveyed the line of junction of the granite and superincumbent stratified masses, until he found in Glen Tilt, in 1785, the most clear and unequivocal proofs in support of his views. Veins of red granite are there seen branching out from the principal mass, and traversing the black micaceous schist and primary limestone. The intersected stratified rocks are so distinct in colour and appearance as to render the example in that locality most striking, and the alteration of the limestone in contact was very analogous to that produced by trap veins on calcareous strata. This verification of his system filled him with delight, and called forth such marks of joy and exultation, that the guides who accompanied him, says his biographer, were convinced that he must have discovered a vein of silver or gold.* He was aware that the same theory would not explain the origin of the primary schists, but these he called primary, rejecting the term primitive, and was disposed to consider them as sedimentary rocks altered by heat, and that they originated in some other form from the waste of previously existing rocks.

By this important discovery of granite veins, to which he had been led by fair induction from an independent class of facts, Hutton prepared the way for the greatest innovation on the systems of his predecessors. Vallisneri had pointed out the general fact that there were certain fundamental rocks which contained no organic remains, and which he supposed to have been formed before the creation of living beings. Moro, Generelli, and other Italian writers, embraced

* Playfair's Works, vol. iv. p. 75.

the same doctrine; and Lehman regarded the mountains called by him primitive, as parts of the original nucleus of the globe. The same tenet was an article of faith in the school of Freyberg; and if any one ventured to doubt the possibility of our being enabled to carry back our researches to the creation of the present order of things, the granitic rocks were triumphantly appealed to. On them seemed written, in legible characters, the memorable inscription —

“Dinanzi a me non fur cose create
Se non eterne;” *

and no small sensation was excited when Hutton seemed, with unhallowed hand, desirous to erase characters already regarded by many as sacred. “In the economy of the world,” said the Scotch geologist, “I can find no traces of a beginning, no prospect of an end;” a declaration the more startling when coupled with the doctrine, that all past changes on the globe had been brought about by the slow agency of existing causes. The imagination was first fatigued and overpowered by endeavouring to conceive the immensity of time required for the annihilation of whole continents by so insensible a process; and when the thoughts had wandered through these interminable periods, no resting place was assigned in the remotest distance. The oldest rocks were represented to be of a derivative nature, the last of an antecedent series, and that, perhaps, one of many pre-existing worlds. Such views of the immensity of past time, like those unfolded by the Newtonian philosophy in regard to space, were too vast to awaken ideas of sublimity

* “ Before me things create were none, save things
Eternal.”

Dante’s Inferno, Canto iii., Cary’s Translation.

unmixed with a painful sense of our incapacity to conceive a plan of such infinite extent. Worlds are seen beyond worlds immeasurably distant from each other, and, beyond them all, innumerable other systems are faintly traced on the confines of the visible universe.

The characteristic feature of the Huttonian theory was, as before hinted, the exclusion of all causes not supposed to belong to the present order of nature. But Hutton had made no step beyond Hooke, Moro, and Raspe, in pointing out in what manner the laws now governing subterranean movements might bring about geological changes, if sufficient time be allowed. On the contrary, he seems to have fallen far short of some of their views, especially when he refused to attribute any part of the external configuration of the earth's crust to subsidence. He imagined that the continents were first gradually destroyed by aqueous degradation; and when their ruins had furnished materials for new continents, they were upheaved by violent convulsions. He therefore required alternate periods of general disturbance and repose: and such he believed had been, and would for ever be, the course of nature.

Generelli, in his exposition of Moro's system, had made a far nearer approximation towards reconciling geological appearances with the state of nature as known to us; for while he agreed with Hutton, that the decay and reproduction of rocks were always in progress, proceeding with the utmost uniformity, the learned Carmelite represented the repairs of mountains by elevation from below to be effected by an equally constant and synchronous operation. Neither of these theories, considered singly, satisfies all the conditions of the great problem, which a geologist,

who rejects cosmological causes, is called upon to solve ; but they probably contain together the germs of a perfect system. There can be no doubt, that periods of disturbance and repose have followed each other in succession in every region of the globe ; but it may be equally true, that the energy of the subterranean movements has been always uniform as regards the *whole earth*. The force of earthquakes may for a cycle of years have been invariably confined, as it is now, to large but determinate spaces, and may then have gradually shifted its position, so that another region, which had for ages been at rest, became in its turn the grand theatre of action.

Playfair's illustrations of Hutton.—The explanation proposed by Hutton and by Playfair, the illustrator of his theory, respecting the origin of valleys and of alluvial accumulations, was also very imperfect. They ascribed none of the inequalities of the earth's surface to movements which accompanied the upheaving of the land, imagining that valleys in general were formed in the course of ages, by the rivers now flowing in them ; while they seem not to have reflected on the excavating and transporting power which the waves of the ocean might exert on land during its emergence.

Although Hutton's knowledge of mineralogy and chemistry was considerable, he possessed but little information concerning organic remains ; they merely served him, as they did Werner, to characterize certain strata, and to prove their marine origin. The theory of former revolutions in organic life was not yet fully recognized ; and without this class of proofs in support of the antiquity of the globe, the indefinite periods demanded by the Huttonian hypothesis appeared visionary to many ; and some, who deemed the doctrine

inconsistent with revealed truths, indulged very uncharitable suspicions of the motives of its author. They accused him of a deliberate design of reviving the heathen dogma of an "eternal succession," and of denying that this world ever had a beginning. Playfair, in the biography of his friend, has the following comment on this part of their theory:—"In the planetary motions, where geometry has carried the eye so far, both into the future and the past, we discover no mark either of the commencement or termination of the present order. It is unreasonable, indeed, to suppose that such marks should any where exist. The Author of Nature has not given laws to the universe, which, like the institutions of men, carry in themselves the elements of their own destruction. He has not permitted in His works any symptom of infancy or of old age, or any sign by which we may estimate either their future or their past duration. *He may put an end, as he no doubt gave a beginning,* to the present system, at some determinate period of time; but we may rest assured that this great catastrophe will not be brought about by the laws now existing, and that it is not indicated by any thing which we perceive." *

The party feeling excited against the Huttonian doctrines, and the open disregard of candour and temper in the controversy, will hardly be credited by the reader, unless he recalls to his recollection that the mind of the English public was at that time in a state of feverish excitement. A class of writers in France had been labouring industriously, for many years, to diminish the influence of the clergy, by sapping the foundations of the Christian faith; and

* Playfair's Works, vol. iv. p. 55.

their success, and the consequences of the Revolution, had alarmed the most resolute minds, while the imagination of the more timid was continually haunted by dread of innovation, as by the phantom of some fearful dream.

Voltaire.— Voltaire had used the modern discoveries in physics as one of the numerous weapons of attack and ridicule directed by him against the Scriptures. He found that the most popular systems of geology were accommodated to the sacred writings, and that much ingenuity had been employed to make every fact coincide exactly with the Mosaic account of the creation and deluge. It was, therefore, with no friendly feelings that he contemplated the cultivators of geology in general, regarding the science as one which had been successfully enlisted by theologians as an ally in their cause.* He knew that the majority of those who were aware of the abundance of fossil shells in the interior of continents, were still persuaded that they were proofs of the universal deluge ; and as the readiest way of shaking this article of faith, he endeavoured to inculcate scepticism as to the real nature of such shells, and to recall from contempt the exploded dogma of the sixteenth century, that they were

* In allusion to the theories of Burnet, Woodward, and other physico-theological writers, he declared that they were as fond of changes of scene on the face of the globe, as were the populace at a play. “ Every one of them destroys and renovates the earth after his own fashion, as Descartes framed it : for philosophers put themselves without ceremony in the place of God, and think to create a universe with a word.”—*Dissertation envoyée à l’Académie de Boulogne, sur les Changemens arrivés dans notre Globe.* Unfortunately, this and similar ridicule directed against the cosmogonists was too well deserved.

sports of nature. He also pretended that vegetable impressions were not those of real plants.* Yet he was perfectly convinced that the shells had really belonged to living testacea, as may be seen in his essay "On the formation of Mountains." † He would sometimes, in defiance of all consistency, shift his ground when addressing the vulgar; and, admitting the true nature of the shells collected in the Alps and other places, pretend that they were Eastern species, which had fallen from the hats of pilgrims coming from Syria. The numerous essays written by him on geological subjects were all calculated to strengthen prejudices, partly because he was ignorant of the real state of the science, and partly from his bad faith. ‡ On the other hand, they who knew that his attacks were directed by a desire to invalidate Scripture, and who were unacquainted with the true merits of the question, might well deem the old diluvian hypothesis incontrovertible, if Voltaire could adduce no better argument against it than to deny the true nature of organic remains.

It is only by careful attention to impediments originating in extrinsic causes, that we can explain the slow and reluctant adoption of the simplest truths in

* See the chapter on "Des Pierres figurées."

† In that essay he lays it down, "that all naturalists are now agreed that deposits of shells in the midst of the continents are monuments of the continued occupation of these districts by the ocean." In another place also, when speaking of the fossil shells of Touraine, he admits their true origin.

‡ As an instance of his desire to throw doubt indiscriminately on all geological data, we may recall the passage where he says, that "the bones of a rein-deer and hippopotamus discovered near Etampes did not prove, as some would have it, that Lapland and the Nile were once on a tour from Paris to Orleans, but merely that a lover of curiosities once preserved them in his cabinet."

geology. First, we find many able naturalists adducing the fossil remains of marine animals as proofs of an event related in Scripture. The evidence is deemed conclusive by the multitude for a century or more ; for it favours opinions which they entertained before, and they are gratified by supposing them confirmed by fresh and unexpected proofs. Many, who see through the fallacy, have no wish to undeceive those who are influenced by it, approving the effect of the delusion, and conniving at it as a pious fraud ; until, finally, an opposite party, who are hostile to the sacred writings, labour to explode the erroneous opinion, by substituting for it another dogma which they know to be equally unsound.

The heretical Vulcanists were soon after openly assailed in England, by imputations of the most illiberal kind. We cannot estimate the malevolence of such a persecution, by the pain which similar insinuations might now inflict : for although charges of infidelity and atheism must always be odious, they were injurious in the extreme at that moment of political excitement ; and it was better, perhaps, for a man's good reception in society, that his moral character should have been traduced, than that he should become a mark for these poisoned weapons.

I shall pass over the works of numerous divines, who may be excused for sensitiveness on points which then excited so much uneasiness in the public mind ; and shall say nothing of the amiable poet Cowper *, who could hardly be expected to have inquired into the merit of doctrines in physics. But in the foremost ranks of the intolerant, are found several laymen who

* *The Task*, book iii. “The Garden.”

had high claims to scientific reputation. Among these appears Williams, a mineral surveyor of Edinburgh, who published a "Natural History of the Mineral Kingdom," in 1789; a work of great merit for that day, and of practical utility, as containing the best account of the coal strata. In his preface he misrepresents Hutton's theory altogether, and charges him with considering all rocks to be lavas of different colours and structure; and also with "warping every thing to support the eternity of the world."* He descants on the pernicious influence of such sceptical notions, as leading to downright infidelity and atheism, "and as being nothing less than to depose the Almighty Creator of the universe from his office."†

Kirwan—De Luc.—Kirwan, president of the Royal Academy of Dublin, a chemist and mineralogist of some merit, but who possessed much greater authority in the scientific world than he was entitled by his talents to enjoy, said, in the introduction to his "Geological Essays, 1799," "that *sound* geology *graduated* into religion, and was required to dispel certain systems of atheism or infidelity, of which they had had recent experience."‡ He was an uncompromising defender of the aqueous theory of all rocks, and was scarcely surpassed by Burnet and Whiston, in his desire to adduce the Mosaic writings in confirmation of his opinions.

De Luc, in the preliminary discourse to his Treatise on Geology §, says, "the weapons have been changed by which revealed religion is attacked; it is now assailed by geology, and the knowledge of this science

* P. 577.

† P. 59.

‡ Introd. p. 2.

§ London, 1809.

has become essential to theologians." He imputes the failure of former geological systems to their having been anti-Mosaical, and directed against a "sublime tradition." These and similar imputations, reiterated in the works of De Luc, seem to have been taken for granted by some modern writers: it is therefore necessary to state, in justice to the numerous geologists of different nations, whose works have been considered, that none of them were guilty of endeavouring, by arguments drawn from physics, to invalidate scriptural tenets. On the contrary, the majority of them who were fortunate enough "to discover the true causes of things," rarely deserved another part of the poet's panegyric, "*Atque metus omnes subjecit pedibus.*" The caution, and even timid reserve, of many eminent Italian authors of the earlier period is very apparent; and there can hardly be a doubt, that they subscribed to certain dogmas, and particularly to the first diluvian theory, out of deference to popular prejudices, rather than from conviction. If they were guilty of dissimulation, we may feel regret, but must not blame their want of moral courage, reserving rather our condemnation for the intolerance of the times, and that inquisitorial power which forced Galileo to abjure, and the two Jesuits to disclaim the theory of Newton.*

* In a most able article, by Mr. Drinkwater, on the "Life of Galileo," published in the "Library of Useful Knowledge," it is stated that both Galileo's work, and the book of Copernicus "Nisi corrigatur" (for, with the omission of certain passages, it was sanctioned), were still to be seen on the forbidden list of the Index at Rome in 1828. I was however assured in the same year, by Professor Scarpellini, at Rome, that Pius VII., a Pontiff distinguished for his love of science, had procured a repeal of the edicts

Hutton answered Kirwan's attacks with great warmth, and with the indignation justly excited by unmerited reproach. "He had always displayed," says Playfair, "the utmost disposition to admire the beneficent design manifested in the structure of the world; and he contemplated with delight those parts of his theory which made the greatest additions to our knowledge of final causes." We may say with equal truth, that in no scientific works in our language can more eloquent passages be found, concerning the fitness, harmony, and grandeur of all parts of the creation, than in those of Playfair. They are evidently the unaffected expressions of a mind, which contemplated the study of nature, as best calculated to elevate our conceptions of the attributes of the First Cause. At any other time the force and elegance of Playfair's style must have insured popularity to the Huttonian doctrines; but, by a singular coincidence, Neptunianism and orthodoxy were now associated in the same creed; and the tide of prejudice ran so strong, that the majority were carried far away into the chaotic fluid, and other cosmological inventions of Werner. These fictions the Saxon professor had borrowed with

against Galileo and the Copernican system. He had assembled the Congregation; and the late Cardinal Toriozzi, assessor of the Sacred Office, proposed "that they should wipe off this scandal from the church." The repeal was carried, with the dissentient voice of one Dominican only. Long before that time the Newtonian theory had been taught in the Sapienza, and all Catholic universities in Europe (with the exception, I am told, of Salamanca); but it was always required of professors, in deference to the decrees of the church, to use the term *hypothesis*, instead of theory. They now speak of the Copernican theory.

little modification, and without any improvement, from his predecessors. They had not the smallest foundation either in Scripture or in common sense, and were probably approved of by many as being so ideal and unsubstantial, that they could never come into violent collision with any preconceived opinions.

According to De Luc, the first essential distinction to be made between the various phenomena exhibited on the surface of the earth was, to determine which were the results of causes still in action, and which had been produced by causes that had ceased to act. The form and composition of the mass of our continents, he said, and their existence above the level of the sea, must be ascribed to causes no longer in action. These continents emerged, at no very remote period, on the sudden retreat of the ocean, the waters of which made their way into subterranean caverns. The formation of the rocks which enter into the crust of the earth began with the precipitation of granite from a primordial liquid, after which other strata containing the remains of organized bodies were deposited, till at last the present sea remained as the residuum of the primordial liquid, and no longer continued to produce mineral strata. *

William Smith, 1790.—While the tenets of the rival schools of Freyberg and Edinburgh were warmly espoused by devoted partisans, the labours of an individual, unassisted by the advantages of wealth or station in society, were almost unheeded. Mr. William Smith, an English surveyor, published his “Tabular View of the British Strata” in 1790, wherein he pro-

* Elementary Treatise on Geology. London, 1809. Translated by De la Fite.

posed a classification of the secondary formations in the West of England. Although he had not communicated with Werner, it appeared by this work that he had arrived at the same views respecting the laws of superposition of stratified rocks; that he was aware that the order of succession of different groups was never inverted; and that they might be identified at very distant points by their peculiar organized fossils.

From the time of the appearance of the "Tabular View," the author laboured to construct a geological map of the whole of England; and, with the greatest disinterestedness of mind, communicated the results of his investigations to all who desired information, giving such publicity to his original views, as to enable his contemporaries almost to compete with him in the race. The execution of his map was completed in 1815, and remains a lasting monument of original talent and extraordinary perseverance; for he had explored the whole country on foot without the guidance of previous observers, or the aid of fellow-labourers, and had succeeded in throwing into natural divisions the whole complicated series of British rocks. D'Aubuisson, a distinguished pupil of Werner, paid a just tribute of praise to this remarkable performance, observing, that "what many celebrated mineralogists had only accomplished for a small part of Germany in the course of half a century, had been effected by a single individual for the whole of England." *

Werner invented a new language to express his divisions of rocks, and some of his technical terms, such as grauwacke, gneiss, and others, passed current in every country in Europe. Smith adopted for the

* See Dr. Fitton's Memoir, before cited, p. 57.

most part English provincial terms, often of barbarous sound, such as gault, cornbrash, clunch clay; and affixed them to subdivisions of the British series. Many of these still retain their place in our scientific classifications, and attest his priority of arrangement.

MODERN PROGRESS OF GEOLOGY,

The contention of the rival factions of the Vulcanists and Neptunists had been carried to such a height, that these names had become terms of reproach; and the two parties had been less occupied in searching for truth, than for such arguments as might strengthen their own cause, or serve to annoy their antagonists. A new school at last arose, who professed the strictest neutrality, and the utmost indifference to the systems of Werner and Hutton, and who resolved diligently to devote their labours to observation. The reaction, provoked by the intemperance of the conflicting parties now produced a tendency to extreme caution. Speculative views were discountenanced, and, through fear of exposing themselves to the suspicion of a bias towards the dogmas of a party, some geologists became anxious to entertain no opinion whatever on the causes of phenomena, and were inclined to scepticism even where the conclusions deducible from observed facts scarcely admitted of reasonable doubt.

Geological Society of London. — But although the reluctance to theorize was carried somewhat to excess, no measure could be more salutary at such a moment than a suspension of all attempts to form what were termed "theories of the earth." A great body of new data were required; and the Geological Society of London, founded in 1807, conducted greatly to the attainment of this desirable end. To multiply and record

observations, and patiently to await the result at some future period, was the object proposed by them; and it was their favourite maxim that the time was not yet come for a general system of geology, but that all must be content for many years to be exclusively engaged in furnishing materials for future generalizations. By acting up to these principles with consistency, they in a few years disarmed all prejudice, and rescued the science from the imputation of being a dangerous, or at best but a visionary pursuit.

A distinguished modern writer has with truth remarked, that the advancement of three of the main divisions of geological inquiry have, during the last half century, been promoted successively by three different nations of Europe,—the Germans, the English, and the French.* We have seen that the systematic study of what may be called mineralogical geology had its origin and chief point of activity, in Germany, where Werner first described with precision the mineral characters of rocks. The classification of the secondary formations, each marked by their peculiar fossils, belongs, in a great measure, to England, where the labours before alluded to of Smith, and those of the most active members of the Geological Society of London, were steadily directed to these objects. The foundation of the third branch, that relating to the tertiary formations, was laid in France by the splendid work of Cuvier and Brongniart, published in 1808, “On the Mineral Geography and Organic Remains of the Neighbourhood of Paris.”

We may still trace, in the language of the science and our present methods of arrangement, the various

* Whewell, *British Critic*, No. xvii. p. 187. 1831.

countries where the growth of these several departments of geology was at different times promoted. Many names of simple minerals and rocks remain to this day German ; while the European divisions of the secondary strata are in great part English, and are, indeed, often founded too exclusively on English types. Lastly, the subdivisions first established of the succession of strata in the Paris basin have served as normal groups, to which other tertiary deposits throughout Europe have been compared, even in cases where this standard, as will afterwards be shown, was wholly inapplicable.*

No period could have been more fortunate for the discovery, in the immediate neighbourhood of Paris, of a rich store of well-preserved fossils, than the commencement of the present century ; for at no former era had Natural History been cultivated with such enthusiasm in the French metropolis. The labours of Cuvier in comparative osteology, and of Lamarck in recent and fossil shells, had raised these departments of study to a rank of which they had never previously been deemed susceptible. Their investigations had eventually a powerful effect in dispelling the illusion which had long prevailed concerning the absence of analogy between the ancient and modern state of our planet. A close comparison of the recent and fossil species, and the inferences drawn in regard to their habits, accustomed the geologist to contemplate the earth as having been at successive periods the dwelling-place of animals and plants of different races, some terrestrial, and others aquatic — some fitted to live in seas, others in the waters of lakes and rivers. By the

* Book iv. chap. ii.

consideration of these topics, the mind was slowly and insensibly withdrawn from imaginary pictures of catastrophes and chaotic confusion, such as haunted the imagination of the early cosmogonists. Numerous proofs were discovered of the tranquil deposition of sedimentary matter, and the slow development of organic life. If many writers, and Cuvier himself in the number, still continued to maintain, that "the thread of induction was broken,"* yet, in reasoning by the strict rules of induction from recent to fossil species, they in a great measure disclaimed the dogma which in theory they professed. The adoption of the same generic, and, in some cases, even of the same specific, names for the exuviae of fossil animals and their living analogues, was an important step towards familiarizing the mind with the idea of the identity and unity of the system in distant eras. It was an acknowledgment, as it were, that part at least of the ancient memorials of nature were written in a living language. The growing importance, then, of the natural history of organic remains may be pointed out as the characteristic feature of the progress of the science during the present century. This branch of knowledge has already become an instrument of great utility in geological classification, and is continuing daily to unfold new data for grand and enlarged views respecting the former changes of the earth.

When we compare the result of observations in the last forty years with those of the three preceding centuries, we cannot but look forward with the most sanguine expectations to the degree of excellence to which geology may be carried, even by the labours of the

* Discours sur les Révol. &c.

present generation. Never, perhaps, did any science, with the exception of astronomy, unfold, in an equally brief period, so many novel and unexpected truths, and overturn so many preconceived opinions. The senses had for ages declared the earth to be at rest, until the astronomer taught that it was carried through space with inconceivable rapidity. In like manner was the surface of this planet regarded as having remained unaltered since its creation, until the geologist proved that it had been the theatre of reiterated change, and was still the subject of slow but never-ending fluctuations. The discovery of other systems in the boundless regions of space was the triumph of astronomy : to trace the same system through various transformations — to behold it at successive eras adorned with different hills and valleys, lakes and seas, and peopled with new inhabitants, was the delightful meed of geological research. By the geometer were measured the regions of space, and the relative distances of the heavenly bodies ;—by the geologist myriads of ages were reckoned, not by arithmetical computation, but by a train of physical events — a succession of phenomena in the animate and inanimate worlds — signs which convey to our minds more definite ideas than figures can do of the immensity of time.

Whether our investigation of the earth's history and structure will eventually be productive of as great practical benefits to mankind as a knowledge of the distant heavens, must remain for the decision of posterity. It was not till astronomy had been enriched by the observations of many centuries, and had made its way against popular prejudices to the establishment of a sound theory, that its application to the useful arts was most conspicuous. The cultivation of geology

began at a later period ; and in every step which it has hitherto made towards sound theoretical principles, it has had to contend against more violent prepossessions. The practical advantages already derived from it have not been inconsiderable : but our generalizations are yet imperfect, and they who come after us may be expected to reap the most valuable fruits of our labour. Meanwhile the charm of first discovery is our own ; and, as we explore this magnificent field of inquiry, the sentiment of a great historian of our times may continually be present to our minds, that " he who calls what has vanished back again into being, enjoys a bliss like that of creating."*

* Niebuhr's Hist. of Rome, vol. i. p. 5. Hare and Thirlwall's translation.

CHAPTER V.

PREJUDICES WHICH HAVE RETARDED THE PROGRESS OF
GEOLOGY.

Prepossessions in regard to the duration of past time — Prejudices arising from our peculiar position as inhabitants of the land — Of those occasioned by our not seeing subterranean changes now in progress — All these causes combine to make the former course of Nature appear different from the present — Objections to the doctrine that causes similar in kind and energy to those now acting, have produced the former changes of the earth's surface, considered.

If we reflect on the history of the progress of geology, as explained in the preceding chapters, we perceive that there have been great fluctuations of opinion respecting the nature of the causes to which all former changes of the earth's surface are referable. The first observers conceived the monuments which the geologist endeavours to decipher to relate to an original state of the earth, or to a period when there were causes in activity, distinct, in kind and degree, from those now constituting the economy of nature. These views were gradually modified, and some of them entirely abandoned in proportion as observations were multiplied, and the signs of former mutations more skilfully interpreted. Many appearances, which had for a long time been regarded as indicating mysterious and extraordinary agency, were finally recognized as the necessary result of the laws now governing

the material world ; and the discovery of this unlooked-for conformity has at length induced some philosophers to infer, that, during the ages contemplated in geology, there has never been any interruption to the agency of the same uniform laws of change. The same assemblage of general causes, they conceive, may have been sufficient to produce, by their various combinations, the endless diversity of effects, of which the shell of the earth has preserved the memorials ; and, consistently with these principles, the recurrence of analogous changes is expected by them in time to come.

Whether we coincide or not in this doctrine, we must admit that the gradual progress of opinion concerning the succession of phenomena in very remote eras, resembles, in a singular manner, that which has accompanied the growing intelligence of every people, in regard to the economy of nature in their own times. In an early stage of advancement, when a great number of natural appearances are unintelligible, an eclipse, an earthquake, a flood, or the approach of a comet, with many other occurrences afterwards found to belong to the regular course of events, are regarded as prodigies. The same delusion prevails as to moral phenomena, and many of these are ascribed to the intervention of demons, ghosts, witches, and other immaterial and supernatural agents. By degrees, many of the enigmas of the moral and physical world are explained, and, instead of being due to extrinsic and irregular causes, they are found to depend on fixed and invariable laws. The philosopher at last becomes convinced of the undeviating uniformity of secondary causes ; and, guided by his faith in this principle, he determines the probability of accounts transmitted to

him of former occurrences, and often rejects the fabulous tales of former times, on the ground of their being irreconcilable with the experience of more enlightened ages.

Prepossessions in regard to the duration of past time.—As a belief in the want of conformity in the causes by which the earth's crust has been modified in ancient and modern periods was, for a long time, universally prevalent, and that, too, amongst men who were convinced that the order of nature had been uniform for the last several thousand years, every circumstance which could have influenced their minds and given an undue bias to their opinions deserves particular attention. Now the reader may easily satisfy himself, that, however undeviating the course of nature may have been from the earliest epochs, it was impossible for the first cultivators of geology to come to such a conclusion, so long as they were under a delusion as to the age of the world, and the date of the first creation of animate beings. However fantastical some theories of the sixteenth century may now appear to us,—however unworthy of men of great talent and sound judgment,—we may rest assured that, if the same misconception now prevailed in regard to the memorials of human transactions, it would give rise to a similar train of absurdities. Let us imagine, for example, that Champollion, and the French and Tuscan literati lately engaged in exploring the antiquities of Egypt, had visited that country with a firm belief that the banks of the Nile were never peopled by the human race before the beginning of the nineteenth century, and that their faith in this dogma was as difficult to shake as the opinion of our ancestors, that the earth was never the abode of living

beings until the creation of the present continents, and of the species now existing,—it is easy to perceive what extravagant systems they would frame, while under the influence of this delusion, to account for the monuments discovered in Egypt. The sight of the pyramids, obelisks, colossal statues, and ruined temples, would fill them with such astonishment, that for a time they would be as men spell-bound—wholly incapable of reasoning with sobriety. They might incline at first to refer the construction of such stupendous works to some superhuman powers of a primeval world. A system might be invented resembling that so gravely advanced by Manetho, who relates that a dynasty of gods originally ruled in Egypt, of whom Vulcan, the first monarch, reigned nine thousand years; after whom came Hercules and other demigods, who were at last succeeded by human kings.

When some fanciful speculations of this kind had amused their imaginations for a time, some vast repository of mummies would be discovered, and would immediately undeceive those antiquaries who enjoyed an opportunity of personally examining them; but the prejudices of others at a distance, who were not eye-witnesses of the whole phenomena, would not be so easily overcome. The concurrent report of many travellers would, indeed, render it necessary for them to accommodate ancient theories to some of the new facts, and much wit and ingenuity would be required to modify and defend their old positions. Each new invention would violate a greater number of known analogies; for if a theory be required to embrace some false principle, it becomes more visionary in proportion as facts are multiplied, as would be the case if geometers were now required to form an astronomical

system on the assumption of the immobility of the earth.

Amongst other fanciful conjectures concerning the history of Egypt, we may suppose some of the following to be started. "As the banks of the Nile have been so recently colonized for the first time, the curious substances called mummies could never in reality have belonged to men. They may have been generated by some *plastic virtue* residing in the interior of the earth, or they may be abortions of nature produced by her incipient efforts in the work of creation. For if deformed beings are sometimes born even now, when the scheme of the universe is fully developed, many more may have been 'sent before their time, scarce half made up,' when the planet itself was in the embryo state. But if these notions appear to derogate from the perfection of the Divine attributes, and if these mummies be in all their parts true representations of the human form, may we not refer them to the future rather than the past? May we not be looking into the womb of Nature, and not her grave? May not these images be like the shades of the unborn in Virgil's Elysium — the archetypes of men not yet called into existence?"

These speculations, if advocated by eloquent writers, would not fail to attract many zealous votaries, for they would relieve men from the painful necessity of renouncing preconceived opinions. Incredible as such scepticism may appear, it has been rivalled by many systems of the sixteenth and seventeenth centuries, and among others by that of the learned Falloppio, who regarded the tusks of fossil elephants as earthy concretions, and the pottery or fragments of vases in the Monte Testaceo, near Rome, as works of nature, and

not of art. But when one generation had passed away, and another, not compromised to the support of antiquated dogmas, had succeeded, they would review the evidence afforded by mummies more impartially, and would no longer controvert the preliminary question, that human beings had lived in Egypt before the nineteenth century: so that when a hundred years perhaps had been lost, the industry and talents of the philosopher would be at last directed to the elucidation of points of real historical importance.

But the above arguments are aimed against one only of many prejudices with which the earlier geologists had to contend. Even when they conceded that the earth had been peopled with animate beings at an earlier period than was at first supposed, they had no conception that the quantity of time bore so great a proportion to the historical era as is now generally conceded. How fatal every error as to the quantity of time must prove to the introduction of rational views concerning the state of things in former ages, may be conceived by supposing the annals of the civil and military transactions of a great nation to be perused under the impression that they occurred in a period of one hundred instead of two thousand years. Such a portion of history would immediately assume the air of a romance; the events would seem devoid of credibility, and inconsistent with the present course of human affairs. A crowd of incidents would follow each other in thick succession. Armies and fleets would appear to be assembled only to be destroyed, and cities built merely to fall in ruins. There would be the most violent transitions from foreign or intestine war to periods of profound peace, and the works effected during the years of disorder or

tranquillity would appear alike superhuman in magnitude.

He who should study the monuments of the natural world under the influence of a similar infatuation, must draw a no less exaggerated picture of the energy and violence of causes, and must experience the same insurmountable difficulty in reconciling the former and present state of nature. If we could behold in one view all the volcanic cones thrown up in Iceland, Italy, Sicily, and other parts of Europe, during the last five thousand years, and could see the lavas which have flowed during the same period ; the dislocations, subsidences, and elevations caused by earthquakes ; the lands added to various deltas, or devoured by the sea, together with the effects of devastation by floods, and imagine that all these events had happened in one year, we must form most exalted ideas of the activity of the agents, and the suddenness of the revolutions. Were an equal amount of change to pass before our eyes in the next year, could we avoid the conclusion that some great crisis of nature was at hand ? If geologists, therefore, have misinterpreted the signs of a succession of events, so as to conclude that centuries were implied where the characters imported thousands of years, and thousands of years where the language of nature signified millions, they could not, if they reasoned logically from such false premises, come to any other conclusion than that the system of the natural world had undergone a complete revolution.

We should be warranted in ascribing the erection of the great pyramid to superhuman power, if we were convinced that it was raised in one day ; and if we imagine, in the same manner, a mountain-chain to have been elevated, during an equally small fraction

of the time which was really occupied in upheaving it, we might then be justified in inferring, that the subterranean movements were once far more energetic than in our own times. We know that one earthquake may raise the coast of Chili for a hundred miles to the average height of about three feet. A repetition of two thousand shocks, of equal violence, might produce a mountain-chain one hundred miles long, and six thousand feet high. Now, should one or two only of these convulsions happen in a century, it would be consistent with the order of events experienced by the Chilians from the earliest times : but if the whole of them were to occur in the next hundred years, the entire district must be depopulated, scarcely any animals or plants could survive, and the surface would be one confused heap of ruin and desolation.

One consequence of undervaluing greatly the quantity of past time, is the apparent coincidence which it occasions of events necessarily disconnected, or which are so unusual, that it would be inconsistent with all calculation of chances to suppose them to happen at one and the same time. When the unlooked-for association of such rare phenomena is witnessed in the present course of nature, it scarcely ever fails to excite a suspicion of the preternatural in those minds which are not firmly convinced of the uniform agency of secondary causes ; — as if the death of some individual in whose fate they are interested happens to be accompanied by the appearance of a luminous meteor, or a comet, or the shock of an earthquake. It would be only necessary to multiply such coincidences indefinitely, and the mind of every philosopher would be disturbed. Now it would be difficult to exaggerate the number of physical events, many of them most

rare and unconnected in their nature, which were imagined by the Woodwardian hypothesis to have happened in the course of a few months : and numerous other examples might be found of popular geological theories, which require us to imagine that a long succession of events happened in a brief and almost momentary period.

Another liability to error, very nearly allied to the former, arises from the frequent contact of geological monuments referring to very distant periods of time. We often behold, at one glance, the effects of causes which have acted at times incalculably remote, and yet there may be no striking circumstances to mark the occurrence of a great chasm in the chronological series of Nature's archives. In the vast interval of time which may really have elapsed between the results of operations thus compared, the physical condition of the earth may, by slow and insensible modifications, have become entirely altered ; one or more races of organic beings may have passed away, and yet have left behind, in the particular region under contemplation, no trace of their existence.

To a mind unconscious of these intermediate events, the passage from one state of things to another must appear so violent, that the idea of revolutions in the system inevitably suggests itself. The imagination is as much perplexed by the deception, as it might be if two distant points in space were suddenly brought into immediate proximity. Let us suppose, for a moment, that a philosopher should lie down to sleep in some arctic wilderness, and then be transferred by a power, such as we read of in tales of enchantment, to a valley in a tropical country, where, on awaking, he might find himself surrounded by birds of brilliant plumage,

and all the luxuriance of animal and vegetable forms of which Nature is so prodigal in those regions. The most reasonable supposition, perhaps, which he could make, if by the necromancer's art he was placed in such a situation, would be, that he was dreaming ; and if a geologist form theories under a similar delusion, we cannot expect him to preserve more consistency in his speculations, than in the train of ideas in an ordinary dream.

It may afford, perhaps, a more lively illustration of the principle here insisted upon, if I recall to the reader's recollection the legend of the Seven Sleepers. The scene of that popular fable was placed in the two centuries which elapsed between the reign of the emperor Decius and the death of Theodosius the younger. In that interval of time (between the years 249 and 450 of our era) the union of the Roman empire had been dissolved, and some of its fairest provinces overrun by the barbarians of the north. The seat of government had passed from Rome to Constantinople, and the throne from a Pagan persecutor to a succession of Christian and orthodox princes. The genius of the empire had been humbled in the dust, and the altars of Diana and Hercules were on the point of being transferred to Catholic saints and martyrs. The legend relates " that when Decius was still persecuting the Christians, seven noble youths of Ephesus concealed themselves in a spacious cavern in the side of an adjacent mountain, where they were doomed to perish by the tyrant, who gave orders that the entrance should be firmly secured with a pile of huge stones. They immediately fell into a deep slumber, which was miraculously prolonged, without injuring the powers of life, during a period of 187 years.

At the end of that time the slaves of Adolius, to whom the inheritance of the mountain had descended, removed the stones to supply materials for some rustic edifice : the light of the sun darted into the cavern, and the seven sleepers were permitted to awake. After a slumber, as they thought, of a few hours, they were pressed by the calls of hunger, and resolved that Jamblichus, one of their number, should secretly return to the city to purchase bread for the use of his companions. The youth could no longer recognize the once familiar aspect of his native country, and his surprise was increased by the appearance of a large cross triumphantly erected over the principal gate of Ephesus. His singular dress and obsolete language confounded the baker, to whom he offered an ancient medal of Decius as the current coin of the empire ; and Jamblichus, on the suspicion of a secret treasure, was dragged before the judge. Their mutual inquiries produced the amazing discovery, that two centuries were almost elapsed since Jamblichus and his friends had escaped from the rage of a Pagan tyrant." *

This legend was received as authentic throughout the Christian world before the end of the sixth century, and was afterwards introduced by Mahomet as a divine revelation into the Koran, and from hence was adopted and adorned by all the nations from Bengal to Africa who professed the Mahometan faith. Some vestiges even of a similar tradition have been discovered in Scandinavia. " This easy and universal belief," observes the philosophical historian of the Decline and Fall, " so expressive of the sense of mankind, may be ascribed to the genuine merit of the fable itself. We

* Gibbon, Decline and Fall, chap. xxxiii.

imperceptibly advance from youth to age, without observing the gradual, but incessant, change of human affairs ; and even in our larger experience of history, the imagination is accustomed, by a perpetual series of causes and effects, to unite the most distant revolutions. But if the interval between two memorable eras could be instantly annihilated ; if it were possible, after a momentary slumber of two hundred years, to display the new world to the eyes of a spectator who still retained a lively and recent impression of the old, his surprise and his reflections would furnish the pleasing subject of a philosophical romance." *

Prejudices arising from our peculiar position as inhabitants of the land.—The sources of prejudice hitherto considered may be deemed peculiar for the most part to the infancy of the science, but others are common to the first cultivators of geology and to ourselves, and are all singularly calculated to produce the same deception, and to strengthen our belief that the course of nature in the earlier ages differed widely from that now established. Although these circumstances cannot be fully explained without assuming some things as proved, which it will be the object of another part of this work to demonstrate, it may be well to allude to them briefly in this place.

The first and greatest difficulty, then, consists in an habitual unconsciousness that our position as observers is essentially unfavourable, when we endeavour to estimate the magnitude of the changes now in progress. In consequence of our inattention to this subject, we are liable to serious mistakes in contrasting the present with former states of the globe.

* Gibbon, *Decline and Fall*, chap. xxxiii.

As dwellers on the land, we inhabit about a fourth part of the surface; and that portion is almost exclusively a theatre of decay, and not of reproduction. We know, indeed, that new deposits are annually formed in seas and lakes, and that every year some new igneous rocks are produced in the bowels of the earth, but we cannot watch the progress of their formation; and as they are only present to our minds by the aid of reflection, it requires an effort both of the reason and the imagination to appreciate duly their importance. It is, therefore, not surprising that we estimate very imperfectly the result of operations thus invisible to us; and that, when analogous results of former epochs are presented to our inspection, we cannot immediately recognize the analogy. He who has observed the quarrying of stone from a rock, and has seen it shipped for some distant port, and then endeavours to conceive what kind of edifice will be raised by the materials, is in the same predicament as a geologist, who, while he is confined to the land, sees the decomposition of rocks, and the transportation of matter by rivers to the sea, and then endeavours to picture to himself the new strata which Nature is building beneath the waters.

Prejudices arising from our not seeing subterranean changes.—Nor is his position less unfavourable when, beholding a volcanic eruption, he tries to conceive what changes the column of lava has produced, in its passage upwards, on the intersected strata; or what form the melted matter may assume at great depths on cooling; or what may be the extent of the subterranean rivers and reservoirs of liquid matter far beneath the surface. It should, therefore, be remembered, that the task imposed on those who study the

earth's history requires no ordinary share of discretion ; for we are precluded from collating the corresponding parts of the system of things as it exists now, and as it existed at former periods. If we were inhabitants of another element — if the great ocean were our domain, instead of the narrow limits of the land, our difficulties would be considerably lessened ; while, on the other hand, there can be little doubt, although the reader may, perhaps, smile at the bare suggestion of such an idea, that an amphibious being, who should possess our faculties, would still more easily arrive at sound theoretical opinions in geology, since he might behold, on the one hand, the decomposition of rocks in the atmosphere, or the transportation of matter by running water ; and, on the other, examine the deposition of sediment in the sea, and the imbedding of animal and vegetable remains in new strata. He might ascertain, by direct observation, the action of a mountain torrent, as well as of a marine current ; might compare the products of volcanos poured out upon the land with those ejected beneath the waters ; and might mark, on the one hand, the growth of the forest, and on the other that of the coral reef. Yet, even with these advantages, he would be liable to fall into the greatest errors when endeavouring to reason on rocks of subterranean origin. He would seek in vain, within the sphere of his observation, for any direct analogy to the process of their formation, and would therefore be in danger of attributing them, wherever they are upraised to view, to some “primeval state of nature.”

But if we may be allowed so far to indulge the imagination, as to suppose a being entirely confined to the nether world — some “dusky melancholy sprite,”

like Umbriel, who could "flit on sooty pinions to the central earth," but who was never permitted to "sully the fair face of light," and emerge into the regions of water and of air ; and if this being should busy himself in investigating the structure of the globe, he might frame theories the exact converse of those usually adopted by human philosophers. He might infer that the stratified rocks, containing shells and other organic remains, were the oldest of created things, belonging to some original and nascent state of the planet. "Of these masses," he might say, "whether they consist of loose incoherent sand, soft clay, or solid stone, none have been formed in modern times. Every year some part of them are broken and shattered by earthquakes, or melted by volcanic fire ; and when they cool down slowly from a state of fusion, they assume a new and more crystalline form, no longer exhibiting that stratified disposition, and those curious impressions and fantastic markings, by which they were previously characterized. This process cannot have been carried on for an indefinite time, for in that case all the stratified rocks would long ere this have been fused and crystallized. It is therefore probable that the whole planet once consisted of these mysterious and curiously bedded formations at a time when the volcanic fire had not yet been brought into activity. Since that period there seems to have been a gradual development of heat ; and this augmentation we may expect to continue till the whole globe shall be in a state of fluidity and incandescence."

Such might be the system of the Gnome at the very time that the followers of Leibnitz, reasoning on what they saw on the outer surface, might be teaching the opposite doctrine of gradual refrigeration, and averring

that the earth had begun its career as a fiery comet, and might be destined hereafter to become a frozen mass. The tenets of the schools of the nether and of the upper world would be directly opposed to each other, for both would partake of the prejudices inevitably resulting from the continual contemplation of one class of phenomena to the exclusion of another. Man observes the annual decomposition of crystalline and igneous rocks, and may sometimes see their conversion into stratified deposits ; but he cannot witness the reconversion of the sedimentary into the crystalline by subterranean fire. He is in the habit of regarding all the sedimentary rocks as more recent than the unstratified, for the same reason that we may suppose him to fall into the opposite error if he saw the origin of the igneous class only.

It was not an impossible contingency, that astronomers might have been placed at some period in a situation much resembling that in which the geologist seems to stand at present. If the Italians, for example, in the early part of the twelfth century, had discovered at Amalfi, instead of the pandects of Justinian, some ancient manuscripts filled with astronomical observations relating to a period of three thousand years, and made by some ancient geometers who possessed optical instruments as perfect as any in modern Europe, they would, probably, on consulting these memorials, have come to a conclusion that there had been a great revolution in the solar and sidereal systems. " Many primary and secondary planets," they might say, " are enumerated in these tables, which exist no longer. Their positions are assigned with such precision, that we may assure ourselves that there is nothing in their place at present but the blue ether. Where one star

is visible to us, these documents represent several thousands. Some of those which are now single consisted then of two separate bodies, often distinguished by different colours, and revolving periodically round a common centre of gravity. There is nothing analogous to them in the universe at present; for they were neither fixed stars nor planets, but seem to have stood in the mutual relation of sun and planet to each other. We must conclude, therefore, that there has occurred, at no distant period, a tremendous catastrophe, whereby thousands of worlds have been annihilated at once, and some heavenly bodies absorbed into the substance of others."

When such doctrines had prevailed for ages, the discovery of some of the worlds, supposed to have been lost (the satellites of Jupiter, for example), by aid of the first rude telescope invented after the revival of science, would not dissipate the delusion, for the whole burden of proof would now be thrown on those who insisted on the stability of the system from a remote period, and these philosophers would be required to demonstrate the existence of *all* the worlds said to have been annihilated.

Such popular prejudices would be most unfavourable to the advancement of astronomy; for, instead of persevering in the attempt to improve their instruments, and laboriously to make and record observations, the greater number would despair of verifying the continued existence of the heavenly bodies not visible to the naked eye. Instead of confessing the extent of their ignorance, and striving to remove it by bringing to light new facts, they would indulge in the more easy and indolent employment of framing imaginary

theories concerning catastrophes and mighty revolutions in the system of the universe.

For more than two centuries the shelly strata of the Subapennine hills afforded matter of speculation to the early geologists of Italy, and few of them had any suspicion that similar deposits were then forming in the neighbouring sea. They were as unconscious of the continued action of causes still producing similar effects, as the astronomers, in the case above supposed, of the existence of certain heavenly bodies still giving and reflecting light, and performing their movements as of old. Some imagined that the strata, so rich in organic remains, instead of being due to secondary agents, had been so created in the beginning of things by the fiat of the Almighty. Others, as we have seen, ascribed the imbedded fossil bodies to some plastic power which resided in the earth in the early ages of the world. In what manner were these dogmas at length exploded? The fossil relics were carefully compared with their living analogues, and all doubts as to their organic origin were eventually dispelled. So, also, in regard to the nature of the containing beds of mud, sand, and limestone: those parts of the bottom of the sea were examined where shells are now becoming annually entombed in new deposits. Donati explored the bed of the Adriatic, and found the closest resemblance between the strata there forming, and those which constituted hills above a thousand feet high in various parts of the Italian peninsula. He ascertained by dredging that living testacea were there grouped together in precisely the same manner as were their fossil analogues in the inland strata; and while some of the recent shells of the Adriatic were becoming incrusted with

calcareous rock, he observed that others had been newly buried in sand and clay, precisely as fossil shells occur in the Subapennine hills. This discovery of the identity of modern and ancient submarine operations was not made without the aid of artificial instruments, which, like the telescope, brought phenomena into view not otherwise within the sphere of human observation.

In like manner, the volcanic rocks of the Vicentin had been studied in the beginning of the last century ; but no geologists suspected, before the time of Arduino, that these were composed of ancient submarine lavas. During many years of controversy, the popular opinion inclined to a belief that basalt and rocks of the same class had been precipitated from a chaotic fluid, or an ocean which rose at successive periods over the continents, charged with the component elements of the rocks in question. Few will now dispute that it would have been difficult to invent a theory more distant from the truth ; yet we must cease to wonder that it gained so many proselytes, when we remember that its claims to probability arose partly from the very circumstance of its confirming the assumed want of analogy between geological causes and those now in action. By what train of investigations were geologists induced at length to reject these views, and to assent to the igneous origin of the trappian formations ? By an examination of volcanos now active, and by comparing their structure and the composition of their lavas with the ancient trap rocks.

The establishment, from time to time, of numerous points of identification, drew at length from geologists a reluctant admission, that there was more correspondence between the condition of the globe at remote

eras and now, and more uniformity in the laws which have regulated the changes of its surface, than they at first imagined. If, in this state of the science, they still despaired of reconciling every class of geological phenomena to the operations of ordinary causes, even by straining analogy to the utmost limits of credibility, we might have expected, at least, that the balance of probability would now have been presumed to incline towards the close analogy of the ancient and modern causes. But, after repeated experience of the failure of attempts to speculate on geological monuments, as belonging to a distinct order of things, new sects continued to persevere in the principles adopted by their predecessors. They still began, as each new problem presented itself, whether relating to the animate or inanimate world, to assume an original and dissimilar order of nature ; and when at length they approximated, or entirely came round to an opposite opinion, it was always with the feeling, that they were conceding what they had been justified *à priori* in deeming improbable. In a word, the same men who, as natural philosophers, would have been most incredulous respecting any extraordinary deviations from the known course of nature, if reported to have happened *in their own time*, were equally disposed, as geologists, to expect the proofs of such deviations at every period of the past.

I shall now proceed to enumerate some of the principal difficulties still opposed to the theory of the uniform nature and energy of the causes which have worked successive changes in the crust of the earth, and in the condition of its living inhabitants. The discussion of so important a question on the present occasion may appear premature, but it is one which

naturally arises out of a review of the former history of the science. It is, of course, impossible to enter into such speculative topics, without occasionally carrying the novice beyond his depth, and appealing to facts and conclusions with which he is as yet unacquainted ; but his curiosity cannot fail to be excited by having his attention at once called to some of the principal points in controversy, and after reading the second, third, and fourth books, he will return, it is hoped, to these preliminary essays with increased interest and profit.

Proofs of former revolutions in climate, as deduced from fossil remains have afforded one of the most popular objections to the theory which endeavours to explain all geological changes by reference to those now in progress on the earth. The probable causes, therefore, of fluctuations in climate, will first be treated of in the following chapters.

CHAPTER VI.

DOCTRINE OF THE DISCORDANCE OF THE ANCIENT AND
MODERN CAUSES OF CHANGE CONTROVERTED.

Climate of the Northern Hemisphere formerly hotter — Direct proofs from the organic remains of the Sicilian and Italian strata — Proofs from analogy derived from extinct quadrupeds — Imbedding of animals in icebergs — Siberian mammoths — Evidence in regard to temperature, from the fossils of tertiary and secondary rocks — From the plants of the coal formation — Northern limit of these fossils — Whether such plants could endure the long continuance of an arctic night.

Climate of the Northern Hemisphere formerly hotter. — THAT the climate of the Northern hemisphere has undergone an important change, and that its mean annual temperature must once have resembled that now experienced within the tropics, was the opinion of some of the first naturalists who investigated the contents of the ancient strata. Their conjecture became more probable when the shells and corals of the secondary rocks were more carefully examined ; for these organic remains were found to be intimately connected by generic affinity with species now living in warmer latitudes. At a later period, many reptiles, such as turtles, tortoises, and large saurian animals, were discovered in European formations in great abundance ; and they supplied new and powerful arguments, from analogy, in support of the doctrine, that the heat of

the climate had been great when our secondary strata were deposited. Lastly, when the botanist turned his attention to the specific determination of fossil plants, the evidence acquired the fullest confirmation ; for the flora of a country is peculiarly influenced by temperature : and the ancient vegetation of the earth might have been expected more readily than the forms of animals, to have afforded conflicting proofs, had the popular theory been without foundation. When the examination of fossil remains was extended to rocks in the most northern parts of Europe and North America, and even to the Arctic regions, indications of the same revolution in climate were discovered.

It cannot be said, that in this, as in many other departments of geology, we have investigated the phenomena of former eras, and neglected those of the present state of things. On the contrary, since the first agitation of this interesting question, the accessions to our knowledge of living animals and plants have been immense, and have far surpassed all the data previously obtained for generalizing, concerning the relation of certain types of organization to particular climates. The tropical and temperate zones of South America and of Australia have been explored ; and, on close comparison, it has been found that scarcely any of the species of the animate creation in these extensive continents are identical with those inhabiting the old world. Yet the zoologist and botanist, well acquainted with the geographical distribution of organic beings in other parts of the globe, would have been able, if distinct groups of species had been presented to them from these regions, to recognize those which had been collected from latitudes within, and those which were brought from without the tropics.

Before I attempt to explain the probable causes of great vicissitudes of temperature on the earth's surface, I shall take a rapid view of some of the principal data which appear to support the popular opinions now entertained on the subject. To insist on the soundness of these inferences, is the more necessary, because some zoologists have of late undertaken to vindicate the uniformity of the laws of nature, not by accounting for former fluctuations in climate, but by denying the value of the evidence in their favour.*

Proofs from fossil shells in tertiary strata. — In Sicily, Calabria, and in the neighbourhood of Naples, the fossil testacea of the most modern tertiary formations belong almost entirely to species now inhabiting the Mediterranean, but as we proceed northwards in the Italian peninsula we find in the strata called Subapennine an assemblage of fossil shells departing somewhat more widely from the type of the neighbouring seas. The proportion of species identifiable with those now living in the Mediterranean is still considerable; but it no longer predominates, as in the South of Italy, over the unknown species. Although occurring in localities which are removed several degrees farther from the equator (as at Sienna, Parma, Asti, &c.), the shells yield clear indications of a hotter climate. Many of them are common to the Subapennine hills, to the Mediterranean, and to the Indian Ocean. Those in the fossil state, and their living analogues from the tropics, correspond in size; whereas the individuals of the same species from the Mediterranean are dwarfish and appear degenerate, and stunted in their growth,

* See two articles by the Rev. Dr. Fleming, in the Edinburgh New Phil. Journ. No. xii. p. 277., April, 1829; and No. xv. p. 65., Jan. 1830.

for want of conditions which the Indian Ocean still supplies.*

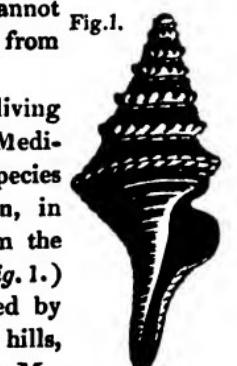
This evidence is of great weight, and is not neutralized by any facts of a conflicting character; such, for instance, as the association, in the same group, of individuals referable to species now confined to arctic regions. Whenever any of the fossil shells are identified with living species foreign to the Mediterranean, it is not in the Northern Ocean, but between the tropics, that they must be sought †: on the other hand, the associated unknown species belong, for the most part, to *genera* which are now most largely developed in equinoctial regions, as, for example, the genera *Cancellaria*, *Cassidaria*, *Pleurotoma*, and *Cypraea*.‡

On comparing the fossils of the tertiary deposits of Paris and London with those of Bordeaux, and these again with the more modern strata of Sicily, we should at first expect that they would each indicate a higher

* Professors Guidotti of Parma, and Bonelli of Turin, pointed out to me, in 1828, many examples in confirmation of this point.

† Thus, for example, *Rostellaria curvirostris*, found fossil by Signor Bonelli near Turin, is only known at present in the Red Sea. *Murex cornutus*, fossil at Asti, is now only known recent in Senegal. *Conus antediluvianus* cannot be distinguished from a shell now brought from Fig. 1. Owbyhee.

‡ Of the genus *Pleurotoma* a very few living representatives have yet been found in the Mediterranean; yet no less than twenty-five species were to be seen in the museum at Turin, in 1828, all procured by Professor Bonelli from the Subapennine strata of northern Italy. (See fig. 1.) The genus *Cypraea* (*Cowrie*) is represented by many large fossil species in the Subapennine hills, and a division of *Cassis*, called *Cypriocassis*, by Mr. S. Stutchbury.



Pleurotoma rotata.
Subapennine hills, Italy.

temperature in proportion as they are situated farther to the south. But the contrary is true; of the shells belonging to these several groups, whether freshwater or marine, some are of extinct, others of living species. Those found in the older, or Eocene, deposits of Paris and London, although six or seven degrees to the north of the Miocene strata at Bordeaux, afford evidence of a warmer climate; while those of Bordeaux imply that the sea in which they lived was of a higher temperature than that of Sicily, where the shelly strata were formed six or seven degrees nearer to the equator. In these cases the greater antiquity of the several formations (the Parisian being the oldest and the Sicilian the newest) has more than counterbalanced the influence which latitude would otherwise exert, and this phenomenon clearly points to a gradual refrigeration of climate.

Siberian Mammoths. — In the superficial deposits of sand, gravel, and loam, strewed very generally over all parts of Europe, the remains of extinct species of land quadrupeds have been found, especially in places where the alluvial matter appears to have been washed into small lakes, or into depressions in the plains bordering ancient rivers. Similar deposits have also been lodged in rents and caverns of rocks, where they may have been swept in by land floods, or introduced by engulfed rivers during changes in the physical geography of these countries. The various circumstances under which the bones of animals have been thus preserved will be more fully considered hereafter *; I shall only state here, that among the extinct mammalia thus entombed, we find species of the elephant, rhinoceros,

* Book iii. chaps. 14, 15, &c.

hippopotamus, bear, hyæna, lion, tiger, and many others; consisting for the most part of genera now confined to warmer regions.

It has been inferred that the same change of climate which has caused certain tropical species of testacea to become rare, or to degenerate in size, or to disappear from the Mediterranean,—and certain *genera* of the Subapennine hills, now chiefly or exclusively tropical, to retain no longer any representatives in the adjoining seas,—may also have contributed to the annihilation of many of the quadrupeds above alluded to. But although it is certainly probable that, when these animals abounded in Europe, the climate was milder than that now experienced, they by no means appear to have required an equatorial heat. The hippopotamus undoubtedly is now only met with in rivers where the temperature of the water is warm and nearly uniform, but the great fossil species of the same genus (*H. major*, Cuv.) inhabited England when the testacea of our country were nearly the same as those now existing, and when the climate cannot be supposed to have been very hot. The bones of this animal have lately been found by Mr. Strickland, together with those of a bear and other mammalia, at Crophorn, near Evesham, in Worcestershire, in alluvial sand, together with twenty-three species of terrestrial and freshwater shells, all, with two exceptions, of British species. The bed of sand, containing the shells and bones, repose on lias, and is covered with alternating strata of gravel, sand and loam.*

The mammoth also appears to have existed in England when the temperature of our latitudes could not

* Geol. Proceedings, No. 36. June, 1834.

have been very different from that which now prevails; for remains of this animal have been found at North Cliff, in the county of York, in a lacustrine formation, in which all the land and freshwater shells, thirteen in number, can be identified with species and varieties now existing in that county. Bones of the bison also, an animal now inhabiting a cold or temperate climate, have been found in the same place. That these quadrupeds, and the indigenous species of testacea associated with them, were all contemporary inhabitants of Yorkshire, has been established by unequivocal proof. The Rev. W. V. Vernon Harcourt caused a pit to be sunk to the depth of twenty-two feet through undisturbed strata, in which the remains of the mammoth were found imbedded, together with the shells, in a deposit, which had evidently resulted from tranquil waters. *

In the valley of the Thames, as at Ilford and Grays, in Essex, bones of the elephant and rhinoceros occur in strata abounding in freshwater shells found of the genera *Unio*, *Cyclas*, *Paludina*, *Valvata*, *Ancylus*, and others. These fossil shells belong for the most part to species now living in the same district, yet some few of them are extinct, as, for example, a species of *Cyrena*, a genus no longer inhabiting Europe, and now entirely restricted to warmer latitudes.

When reasoning on such phenomena, the reader must always bear in mind that the fossil individuals belonged to *species* of elephant, rhinoceros, hippopotamus, bear, tiger, and hyaena, distinct from those which now dwell within or near the tropics. Dr. Fleming, in a discussion on this subject, has well re-

* Phil. Mag., Sept. 1829 and Jan. 1830.

marked that a near resemblance in form and osteological structure is not always followed, in the existing creation, by a similarity of geographical distribution ; and we must therefore be on our guard against deciding too confidently, from mere analogy of anatomical structure, respecting the habits and physiological peculiarities of *species*, now no more. "The zebra delights to roam over the tropical plains ; while the horse can maintain its existence throughout an Iceland winter. The buffalo, like the zebra, prefers a high temperature, and cannot thrive even where the common ox prospers. The musk ox, on the other hand, though nearly resembling the buffalo, prefers the stinted herbage of the arctic regions, and is able, by its periodical migrations, to outlive a northern winter. The jackal (*Canis aureus*) inhabits Africa, the warmer parts of Asia, and Greece ; while the *isatis* (*Canis lagopus*) resides in the arctic regions. The African hare and the polar hare have their geographical distribution expressed in their trivial names * ;" and different species of bears thrive in tropical, temperate, and arctic latitudes.

Recent investigations have placed beyond all doubt the important fact that a species of tiger, identical with that of Bengal, is common in the neighbourhood of Lake Aral, near Sussac, in the forty-fifth degree of north latitude ; and from time to time this animal is now seen in Siberia, in a latitude as far north as the parallel of Berlin and Hamburgh.† Humboldt re-

* Fleming, Ed. New Phil. Journ., No. 12. p. 282. 1829.
The zebra, however, inhabits chiefly the extra-tropical parts of Africa.

† Humboldt, Fragmens de Géologie, &c., tome ii. p. 388.
Ehrenberg, Ann. des Sci. Nat., tome xxi. p. 387.

marks that the part of southern Asia now inhabited by this Indian species of tiger is separated from the Himalaya by two great chains of mountains, each covered with perpetual snow,—the chain of Kuenlun, lat. 35° N., and that of Mouztagh, lat. 42°,—so that it is impossible that these animals should merely have made excursions from India, so as to have penetrated in summer to the forty-eighth and fifty-third degrees of north latitude. They must remain all the winter north of the Mouztagh, or Celestial Mountains. The last tiger killed, in 1828, on the Lena, in lat. $52\frac{1}{4}$ °, was in a climate colder than that of Petersburg and Stockholm.*

We learn from Mr. Hodgson's account of the mammalia of Nepal, that the tiger is sometimes found at the very edge of perpetual snow in the Himalaya†; and Pennant mentions that it is found among the snows of Mount Ararat in Armenia. The Jaguar, also, has been seen on the banks of the Rio Negro, in lat. 41° S., and even as far as 42° S. in South America,—a latitude which corresponds to that of the Pyrenees in the northern hemisphere.‡ The range of the Puma is still wider, for it roams from the equator to the Straits of Magellan, being often seen at Port Famine, in lat. 53° 38' S.

A new species of panther (*Felis irbis*), covered with long hair, has been discovered in Siberia, evidently inhabiting, like the tiger, a region north of the Celestial Mountains, which are in lat. 42°.§

* Ehrenberg, *ibid.* p. 390.

† *Journ. of Asiat. Soc.*, vol. i. p. 240.

‡ Darwin's *Journal of Travels in South America, &c.* 1832 to 1836, in *Voyage of H.M.S. Beagle*, p. 159.

§ Ehrenberg, *ibid.*

The two-horned African rhinoceros occurs without the tropics at the Cape of Good Hope, in lat. $34^{\circ} 29' S.$, where it is accompanied by the elephant, hippopotamus, and hyæna. Here the migration of all these species towards the south is arrested by the ocean ; but, if the continent had been prolonged still farther, and the land had been of moderate elevation, it is very probable that they might have extended their range to a greater distance from the tropics.

Now, if the Indian tiger can range in our own times to the southern borders of Siberia, or skirt the snows of the Himalaya, and if the puma can reach the fifty-third degree of latitude in South America, we may easily understand how large species of the same genera may once have inhabited our temperate climates. The mammoth (*E. primigenius*), already alluded to as occurring fossil in England, was decidedly different from the two existing species of elephants, one of which is limited to Asia, south of the 31° of N. lat., the other to Africa, where it extends, as before stated, as far south as the Cape of Good Hope. The bones of the great fossil species are very widely spread over Europe and North America ; but are nowhere in such profusion as in Siberia, particularly near the shores of the Frozen Ocean. Are we, then, to conclude that this animal preferred a polar climate ? If so, it may well be asked, by what food was it sustained, and why does it not still survive near the arctic circle ?

Pallas and other writers describe the bones of the mammoth as abounding throughout all the Lowland of Siberia, stretching in a direction west and east, from the borders of Europe to the extreme point nearest America, and south and north, from the base of the mountains of central Asia to the shores of the arctic

sea. (See map, p. 143.) Within this space, scarcely inferior in area to the whole of Europe, fossil ivory has been collected almost every where, on the banks of the Irtish, Oby, Yenesei, Lena, and other rivers. The elephantine remains do not occur in the marshes and low plains, but where the banks of the rivers present lofty precipices of sand and clay; from which circumstance Pallas very justly inferred that, if sections could be obtained, similar bones might be found in all the elevated lands intervening between the great rivers. Strahlenberg, indeed, had stated, before the time of Pallas, that wherever any of the great rivers overflowed and cut out fresh channels during floods, more fossil remains of the same kind were invariably disclosed.

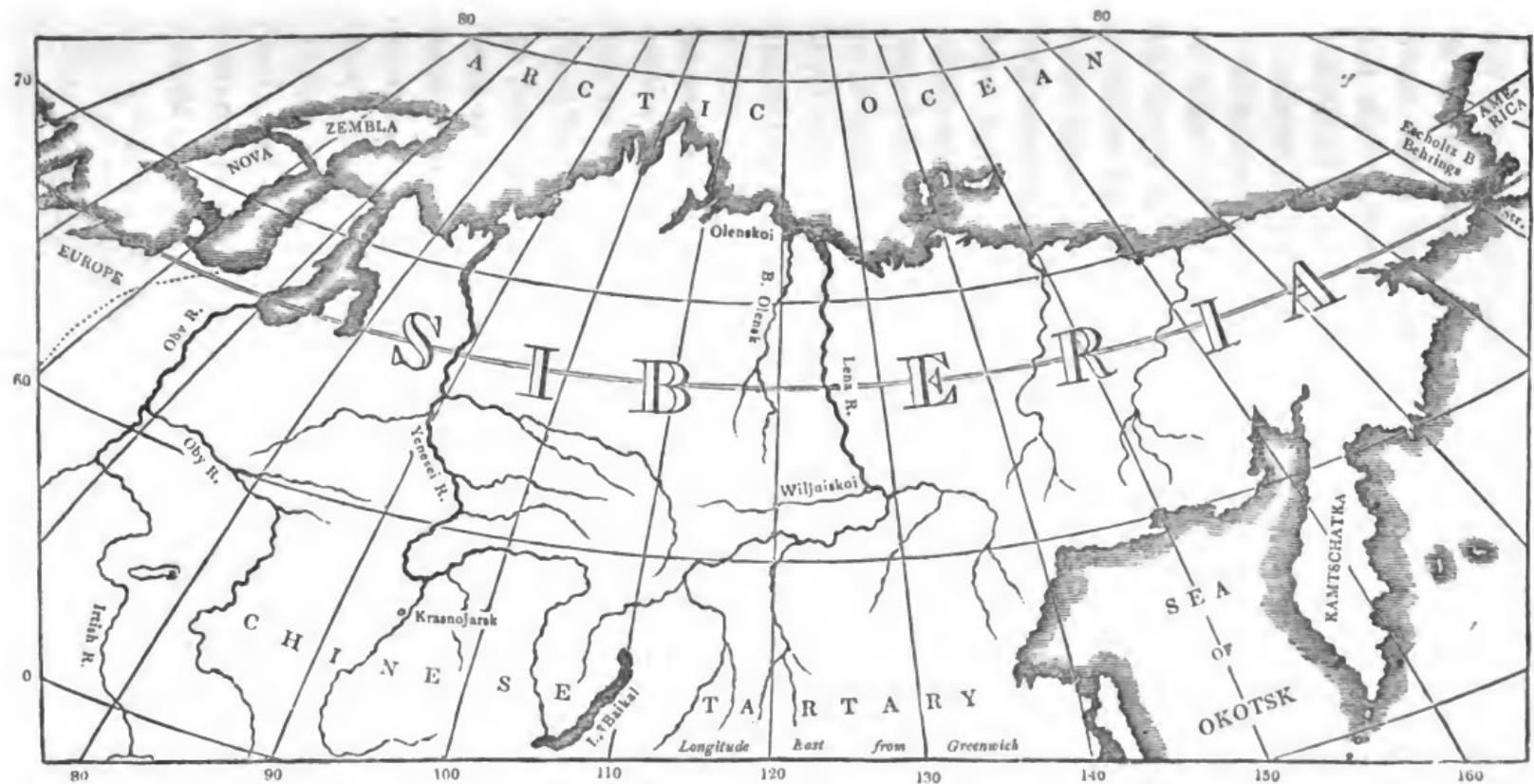
As to the position of the bones, Pallas found them in some places imbedded together with marine remains; in others, simply with fossil wood, or lignite, such, as he says, might have been derived from carbonized peat. On the banks of the Yenesei, below the city of Krasnojarsk, in lat. 56° , he observed grinders, and bones of elephants, in strata of yellow and red loam, alternating with coarse sand and gravel, in which was also much petrified wood of the willow and other trees. Neither here nor in the neighbouring country were there any marine shells, but merely layers of black coal.* But grinders of the mammoth were collected much farther down the same river, near the sea, in lat. 70° , mixed with *marine* petrifactions.† Many other places in Siberia are cited by Pallas, where sea shells and fishes' teeth accompany the bones of the mammoth, rhinoceros, and Siberian buffalo, or bison

* Pallas, *Reise in Russ.* Reiche, pp. 409, 410.

† Nov. Com. Petrop. vol. 17. p. 584.

MAP OF SIBERIA.

Fig. 2.



Map showing the course of the Siberian rivers from south to north, from temperate to arctic regions, in the country where the fossil bones of the Mammoth abound.

(*Bos priscus*). But it is not on the Oby nor the Yenesei, but on the Lena, farther to the east, where, in the same parallels of latitude, the cold is far more intense, that fossil remains have been found in the most wonderful state of preservation. In 1772, Pallas obtained from Wiljuiskoi, in lat. 64° , from the banks of the Wiljui, a tributary of the Lena, the carcass of a rhinoceros (*R. tichorhinus*), taken from the sand in which it must have remained congealed for ages, the soil of that region being always frozen to within a slight depth of the surface. This carcass was compared to a natural mummy, and emitted an odour like putrid flesh, part of the skin being still covered with black and grey hairs. So great, indeed, was the quantity of hair on the foot and head conveyed to St. Petersburg, that Pallas asked whether the rhinoceros of the Lena might not have been an inhabitant of the temperate regions of middle Asia, its clothing being so much warmer than that of the African rhinoceros.*

After more than thirty years, the entire carcass of a mammoth (or extinct species of elephant) was obtained in 1803, by Mr. Adams, much farther to the north. It fell from a mass of ice, in which it had been encased, on the banks of the Lena, in lat. 70° ; and so perfectly had the soft parts of the carcass been preserved, that the flesh, as it lay, was devoured by wolves and bears. This skeleton is still in the museum of St. Petersburg, the head retaining its integument and many of the ligaments entire. This skin of the animal was covered, first, with black bristles, thicker than horse hair, from twelve to sixteen inches in length; secondly with hair of a reddish brown colour, about

* Nov. Com. Petrop. vol. 17. p. 591.

four inches long; and thirdly, with wool of the same colour as the hair, about an inch in length. Of the fur, upwards of thirty pounds' weight were gathered from the wet sand-bank. The individual was nine feet high and sixteen feet long, without reckoning the large curved tusks: a size rarely surpassed by the largest living male elephants.*

It is evident, then, that the mammoth, instead of being naked, like the living Indian and African elephants, was enveloped in a thick shaggy covering of fur, probably as impenetrable to rain and cold as that of the musk ox.† The species may have been fitted by

* Journal du Nord, St. Petersburg, 1807.

† Fleming, Ed. New Phil. Journ., No. xii., p. 285.

Bishop Heber informs us (Narr. of a Journey through the Upper Provinces of India, vol. ii. p. 166—219.), that in the lower range of the Himalaya mountains, in the north-eastern borders of the Delhi territory, between lat. 29° and 30°, he saw an Indian elephant of a small size, covered with shaggy hair. But this variety must be exceedingly rare; for Mr. Royle (late superintendent of the East India Company's Botanic Garden at Saharunpore) has assured me, that being in India when Heber's Journal appeared, and having never seen or heard of such elephants, he made the strictest inquiries respecting the fact, and was never able to obtain any evidence in corroboration. Mr. Royle resided at Saharunpore, lat. 30° N., upon *the extreme northern limit* of the range of the elephant. Mr. Everest also declares that he has been equally unsuccessful in finding any one aware of the existence of such a variety or breed of the animal, though one solitary individual was mentioned to him as having been seen at Delhi, with a good deal of long hair upon it. The greatest elevation, says Mr. E., at which the wild elephant is found in the mountains to the north of Bengal, is at a place called Nahun, about 4000 feet above the level of the sea, and in the 31st degree of N. lat., where the mean yearly temperature may be about 64° Fahrenheit, and the difference between winter and summer very great, equal to about

nature to withstand the vicissitudes of a northern climate; and it is certain that, from the moment when the carcasses, both of the rhinoceros and elephant, above described, were buried in Siberia, in latitudes 64° and 70° N., the soil must have remained frozen, and the atmosphere nearly as cold as at this day.

So fresh is the ivory throughout northern Russia, that, according to Tilesitus, thousands of fossil tusks have been collected and used in turning; yet others are still procured and sold in great plenty. He declares his belief that the bones still left in northern Russia must greatly exceed in number all the elephants now living on the globe.

We are as yet ignorant of the entire geographical range of the mammoth; but its remains have been recently collected from the cliffs of frozen mud and ice on the east side of Behring's Straits, in Eschscholtz's Bay, in Russian America, lat. 66° N. As the cliffs waste away by the thawing of the ice, tusks and bones fall out, and a strong odour of animal matter is exhaled from the mud.*

On considering all the facts above enumerated, it seems reasonable to imagine that a large region in central Asia, including, perhaps, the southern half of Siberia, enjoyed, at no very remote period in the earth's history, a temperate climate, sufficiently mild to afford food for numerous herds of elephants and rhinoceroses, *of species distinct from those now living.* It has usually

36° F., the month of January averaging 45°, and June, the hottest month, 81° F. (Everest on climate of Foss. Eleph., Journ. of Asiatic Soc., No. 25. p. 21.)

* See Dr. Buckland's description of these bones, Appen. to Beechey's Voy.

been taken for granted that herbivorous animals, of large size, require a very luxuriant vegetation for their support; but this opinion is, according to Mr. Darwin, completely erroneous: — “It has been derived,” he says, “from our acquaintance with India and the Indian islands, where the mind has been accustomed to associate troops of elephants with noble forests and impenetrable jungles. But the southern parts of Africa, from the tropic of Capricorn to the Cape of Good Hope, although sterile and desert, are remarkable for the number and great bulk of their indigenous quadrupeds. We there meet with an elephant, five species of rhinoceros, an hippopotamus, a giraffe, the bos caffer, the elan, two zebras, the quagga, two gnus, and several antelopes. Nor must we suppose, that while the species are numerous, the individuals of each kind are few. Dr. Smith saw, in one day’s march, in lat. 24° S., without wandering to any great distance on either side, about 150 rhinoceroses, with several herds of giraffes, and his party had killed, on the previous night, eight hippopotamuses. Yet the country which they inhabited was thinly covered with grass and bushes about four feet high, and still more thinly with mimosa-trees, so that the waggons of the travellers were not prevented from proceeding in a nearly direct line.” *

In order to explain how so many animals can find support in this region, it is suggested, that the underwood, of which their food chiefly consists, may contain much nutriment in a small bulk, and also that the vegetation has a rapid growth; for no sooner is a part

* Darwin, Journal of Travels in S. America, &c., 1832—1836, in voyage of H. M. S. Beagle, p. 98.

consumed, than its place, says Dr. Smith, is supplied by a fresh stock. Nevertheless, after making every allowance for this successive production and consumption, it is clear from the facts above cited, that the quantity of food required by the larger herbivora is much less than we have usually imagined. Mr. Darwin conceives that the amount of vegetation supported at any one time by Great Britain may exceed, in a ten-fold ratio, the quantity existing on an equal area in the interior parts of Southern Africa.* It is remarked, moreover, in illustration of the small connexion discoverable between abundance of food and the magnitude of indigenous mammalia, that while in the desert part of Southern Africa there are so many huge animals, in Brazil, where the splendour and exuberance of the vegetation are unrivalled, there is not a single wild quadruped of large size.†

It would doubtless be impossible for herds of mammoths and rhinoceroses to subsist, at present, throughout the year, even in the southern part of Siberia, covered as it is with snow during winter: but there is no difficulty in supposing a vegetation capable of nourishing these great quadrupeds to have once flourished between the latitudes 40° and 60° N.

Dr. Fleming has hinted, that "the kind of food which the existing species of elephant prefers will not enable us to determine, or even to offer a probable conjecture, concerning that of the extinct species. No one acquainted with the gramineous character of the food of our fallow-deer, stag, or roe, would have assigned a lichen to the rein-deer."

* Darwin, *Journal of Travels in S. America, &c.*, p. 99.

† Burchell, cited by Darwin, *ibid.*, p. 101.

Travellers mention that, even now, when the climate of eastern Asia is so much colder than the same parallels of latitude farther west, there are woods not only of fir, but of birch, poplar, and alder on the banks of the Lena as far north as latitude 60°.

It has, moreover, been suggested, that as, in our own times, the northern animals migrate, so the Siberian elephant and rhinoceros may have wandered towards the north in summer. The musk oxen annually desert their winter quarters in the south, and cross the sea upon the ice, to graze for four months, from May to September, on the rich pasturage of Melville Island, in lat. 75°. The mammoths, without passing so far beyond the arctic circle, may nevertheless have made excursions, during the heat of a brief northern summer, from the central or temperate parts of Asia to the sixtieth parallel of latitude.

Now, in this case, the preservation of their bones, or even occasionally of their entire carcasses, in ice or frozen soil, may be accounted for without resorting to speculations, concerning sudden revolutions in the former state and climate of the earth's surface. We are entitled to assume, that in the time of the extinct elephant and rhinoceros the Lowland of Siberia was less extensive towards the north than now; for we have seen (p. 143.) that the strata of this Lowland, in which the fossil bones lie buried, were originally deposited beneath the sea; and we know, from the facts brought to light in Wrangel's Voyage, in the years 1821, 1822, and 1823, that a slow upheaval of the land along the borders of the Icy Sea is now constantly taking place, similar to that experienced in part of Sweden. In the same manner, then, as the shores of the Gulf of Bothnia are extended not only

by the influx of sediment brought down by rivers, but also by the elevation and consequent drying up of the bed of the sea, so a like combination of causes may, in modern times, have been extending the low tract of land where marine shells and fossil bones occur in Siberia. Such a change in the physical geography of that region, implying a constant augmentation in the quantity of arctic land, would, according to principles to be explained in the next chapter, tend to increase the severity of the winters. We may conclude, therefore, that, before the land reached so far to the north, the temperature of the Siberian winter and summer was more nearly equalized; and a greater degree of winter's cold may, even more than a general diminution of the mean annual temperature, have finally contributed to the extermination of the mammoth and its contemporaries.

On referring to the map (p. 143.), the reader will see how all the great rivers of Siberia flow at present from south to north, from temperate to arctic regions, and they are all liable, like the Mackenzie, in North America, to remarkable floods, in consequence of flowing in this direction. For they are filled with running water in their upper or southern course when completely frozen over for several hundred miles near their mouths, where they remain blocked up by ice for six months in every year. The descending waters, therefore, finding no open channel, rush over the ice, often changing their direction, and sweeping along forests and prodigious quantities of soil and gravel mixed with ice. Now the rivers of Siberia are among the largest in the world, the Yenesei having a course of 2500, the Lena of 2000 miles; so that we may easily conceive that the bodies of animals which fall

into their waters may be transported to vast distances towards the arctic sea, and, before arriving there, may be stranded upon and often frozen into thick ice. Afterwards, when the ice breaks up, they may be floated still farther towards the ocean, until at length they become buried in fluviatile and submarine deposits near the mouths of rivers.

Humboldt remarks that near the mouths of the Lena a considerable thickness of frozen soil may be found at all seasons at the depth of a few feet; so that if a carcass be once imbedded in mud and ice in such a region and in such a climate, its putrefaction may be arrested for indefinite ages.* According to Prof. Von Baer of St. Petersburg, the ground is now frozen permanently to the depth of 400 feet, at the town of Yakutzt, on the western bank of the Lena, in lat. 62° N., 600 miles distant from the polar sea. We may conceive, therefore, that even at the period of the mammoth, when the Lowland of Siberia was less extensive towards the north, and consequently the climate more temperate than now, the cold may still have been sufficiently intense to cause the rivers flowing in their present direction, to sweep down from south to north the bodies of drowned animals, and there bury them in drift ice and frozen mud.

If it be true that the carcass of the mammoth was imbedded in pure ice, we may suppose the animal to have been overwhelmed by drift snow. I have been informed by Dr. Richardson, that in the northern parts of America, comprising regions now inhabited by many herbivorous quadrupeds, the drift snow is often converted into permanent glaciers. It is com-

* Humboldt, *Fragmens Asiatiques*, tom. ii. p. 393.

monly blown over the edges of steep cliffs, so as to form an inclined talus hundreds of feet high ; and when a thaw commences, torrents rush from the land, and throw down from the top of the cliff alluvial soil and gravel. This new soil soon becomes covered with vegetation, and protects the foundation of snow from the rays of the sun. Water occasionally penetrates into the crevices and pores of the snow ; but, as it soon freezes again, it serves the more rapidly to consolidate the mass into a compact iceberg. It may sometimes happen that cattle grazing in a valley at the base of such cliffs, on the borders of a sea or river, may be overwhelmed, and at length enclosed in solid ice, and then transported towards the polar regions.

The foregoing investigations, therefore, lead us to infer that the mammoth, and some other extinct quadrupeds fitted to live in high latitudes, may have been inhabitants of Northern Asia at a time when the climate was milder, and more uniform, than at present. But the strata, it must be remembered, in which the lost species of mammalia above alluded to are found, belong to the most modern tertiary period ; and we have already seen that the older tertiary deposits afford evidence, from their fossil shells, of a temperature much higher, and increasing in proportion to their greater antiquity. In the oldest of these, for example, or those called Eocene, we find shells of the genus *Nautilus*, and other forms now characteristic of the tropics, as many reptiles, for example, resembling in structure those of warmer latitudes, such as the crocodile, turtle, and tortoise.

Proofs from fossils in secondary and still older strata.
— A great interval of time appears to have elapsed between the formation of the secondary strata, which

constitute the principal portion of the elevated land in Europe, and the origin of the last-mentioned Eocene deposits. If we examine the rocks from the New Red sandstone to the Chalk inclusive, we find many distinct assemblages of fossils entombed in them, all of unknown species, and many of them referable to genera and families now most abundant between the tropics. Among the most remarkable are reptiles of gigantic size; some of them herbivorous, others carnivorous, and far exceeding in size any now known even in the torrid zone. The genera are for the most part extinct, but some of them, as the crocodile and monitor, have still representatives in the warmer parts of the earth. Coral reefs also were evidently numerous in the seas of the same periods, and composed of species belonging to genera now characteristic of a tropical climate. The number of very large chambered shells also leads us to infer an elevated temperature; and the associated fossil plants, although imperfectly known, tend to the same conclusion, the Cycadeæ constituting the most numerous family.

But it is from the more ancient coal deposits that the most extraordinary evidence has been supplied in proof of the former existence of an extremely hot climate in those latitudes which are now the temperate and colder regions of the globe. It appears from the fossils of the carboniferous period, that the flora consisted almost exclusively of large vascular cryptogamic plants. We learn from the labours of M. Ad. Brongniart, that there existed at that epoch Equisetaceæ upwards of ten feet high, and from five to six inches in diameter; large arborescent ferns of the genus Caulopteris and other trees probably allied to them called Sigillariæ, from forty to fifty feet in

height; and arborescent Lycopodiaceæ, from sixty to seventy feet high.* Of the above classes of vegetables, the species are all small at present in cold climates; while in tropical regions there occur, together with small species, many of a much greater size, but their development, even in the hottest parts of the globe, is now inferior to that indicated by the petrified forms of the coal formation. An elevated and uniform temperature, and great humidity in the air, are the causes most favourable to the numerical predominance and the great size of these plants within the torrid zone at present. It is true that, as the fossil flora consists of such plants as may accidentally have been floated into seas, lakes, or estuaries, it may very commonly give a false representation of the numerical relations of families then living on the land. Yet, after allowing for liability to error on these grounds, the argument founded on the comparative numbers of the fossil plants of the carboniferous strata is very strong.

"In regard to the geographical extent of the ancient vegetation, it was not confined," says M. Brongniart, "to a small space, as to Europe, for example; for the same forms are met with again at great distances. Thus, the coal plants of North America are, for the most part, identical with those of Europe, and all belong to the same genera. Some specimens, also, from Greenland, are referable to ferns, analogous to those of our European coal mines."† The fossil plants brought from Melville Island, although in a very imperfect state, have been supposed to warrant similar

* Consid. Générales sur la Nature de la Végétation, &c. Ann. des Sci. Nat., Nov. 1828.

† Prodrome d'une Hist. des Végét. Foss. p. 179.

conclusions * ; and assuming that they agree with those of Baffin's Bay, mentioned by M. Brongniart, how shall we explain the manner in which such a vegetation lived through an arctic night of several month's duration ? †

It may seem premature to discuss this question, until the true nature of the fossil flora of the arctic regions has been more accurately determined ; yet, as the question has attracted some attention, let us assume for a moment, that the coal plants of Melville Island are strictly analogous to those of the strata of Northumberland — would such a fact present an inexplicable enigma to the vegetable physiologist ?

Plants, it is affirmed, cannot remain in darkness, even for a week, without serious injury, unless in a torpid state ; and if exposed to heat and moisture they cannot remain torpid, but will grow, and must therefore perish. If, then, in the latitude of Melville Island, 75° N., a high temperature, and consequent humidity, prevailed at that period when we know the arctic seas were filled with corals and large multilocular shells, how could plants of tropical forms have flourished ? Is not the bright light of equatorial regions as indispensable a condition of their well-being as the sultry heat of the same countries ? and how could they annually endure a night prolonged for three months ? ‡

* König, Journ. of Sci. vol. xv. p. 20. Mr. König informs me, that he no longer believes any of these fossils to be tree ferns, as he at first stated, but that they agree with tropical forms of plants in our English coal-beds. The Melville Island specimens, now in the British Museum, are very obscure impressions.

† Fossil Flora of Great Britain, by John Lindley and William Hutton, Esqrs. No. IV.

‡ Ibid.

Now, in reply to this objection, we must bear in mind, in the first place, that, so far as experiments have been made, there is every reason to conclude, that the range of intensity of light to which living plants can accommodate themselves is far wider than that of heat. No palms or tree ferns can live in our temperate latitudes without protection from the cold; but when placed in hot-houses they grow luxuriantly, even under a cloudy sky, and where much light is intercepted by the glass and frame-work. At St. Petersburg, in lat. 60° N., these plants have been successfully cultivated in hot-houses, although there they must exchange the perpetual equinox of their native regions for days and nights which are alternately protracted to nineteen hours and shortened to five. How much farther towards the pole they might continue to live, provided a due quantity of heat and moisture were supplied, has not yet been determined; but St. Petersburg is probably not the utmost limit, and we should expect that in lat. 65° at least, where they would never remain twenty-four hours without enjoying the sun's light, they might still exist.

It should also be borne in mind, in regard to tree ferns, that they grow in the gloomiest and darkest parts of the forests of warm and temperate regions, even extending to nearly the 46th degree of South latitude in New Zealand. In equatorial countries, says Humboldt, they abound chiefly in the temperate, humid, and shady parts of *mountains*. As we know, therefore, that elevation often compensates for the effect of latitude in the geographical distribution of plants, we may easily understand that a class of vegetables, which grow at a certain height in the torrid zone, would flourish on the plains at greater distances from the equator, if

the temperature, moisture, and other necessary conditions, were equally uniform throughout the year.

Nor must we forget that in all the examples above alluded to we have been speaking of *living* species ; but the coal-plants were of perfectly distinct species, and may have been endowed with a different constitution, enabling them to bear a greater variation of circumstances in regard to light. We find that particular species of plants and tree ferns require at present different degrees of heat ; and that some species can thrive only in the immediate neighbourhood of the equator, others only at a distance from it. In the same manner the *minimum* of *light*, sufficient for the now existing species, cannot be taken as the standard for all analogous tribes that may ever have flourished on the globe.

But granting that the extreme northern point to which a flora like that of the carboniferous era could ever reach may be somewhere between the latitudes of 65° and 70° , we should still have to inquire whether the vegetable remains might not have been drifted from thence, by rivers and currents, to the parallel of Melville Island, or still farther. In the northern hemisphere, at present, we see that the materials for future beds of lignite and coal are becoming amassed in high latitudes, far from the districts where the forests grew, and on shores where scarcely a stunted shrub can now exist. The Mackenzie, and other rivers of North America, carry pines with their roots attached for many hundred miles towards the north, into the arctic sea, where they are imbedded in deltas, and some of them drifted still farther by currents towards the pole.

Before we can decide on this question of transportation, we must know whether the fossil coal-plants occurring in high latitudes bear the marks of friction

and of having decayed previously to fossilization. Many appearances in our English coal-fields certainly prove that the plants were not floated from great distances; for the outline of the stems of succulent species preserve their sharp angles, and others have their surfaces marked with the most delicate lines and streaks. Long leaves, also, are attached in many instances to the trunks or branches *; and leaves we know, in general, are soon destroyed when steeped in water, although ferns will retain their forms after an immersion of many months.† It seems fair to presume that the coal plants may have grown upon the same land, the destruction of which provided materials for the sandstones and conglomerates of the group of strata in which they are imbedded; especially as the coarseness of the particles of many of these rocks attests that they were not borne from very remote localities.

To return, therefore, from this digression,—the flora of the coal appears to indicate a high temperature in the air, while the fossils of the contemporaneous mountain-limestone, comprising abundance of lamelliferous corals, large chambered cephalopods, and crinoidea, naturally lead us to infer a great warmth in the waters of the northern sea of the carboniferous period. So also in regard to strata older than the coal, they contain in high northern latitudes mountain masses of corals which must have lived and grown on the spot, and large chambered univalves, such as Orthocerata, which indicate even in regions bordering on the arctic

* Fossil Flora, No. X.

† This has been proved by Mr. Lindley's experiments, *ibid.*, No. XVII.

circle, the former prevalence of an elevated temperature.

The heat and humidity of the air, and the uniformity of climate, appear to have been most remarkable when some of the oldest of the fossiliferous strata were formed. The approximation to a climate similar to that now enjoyed in these latitudes does not commence till the era of the formations termed tertiary ; and while the different tertiary rocks were deposited in succession, the temperature seems to have been still further lowered, and to have continued to diminish gradually, even after the appearance upon the earth of a great portion of the existing species.

CHAPTER VII.

FARTHER EXAMINATION OF THE QUESTION AS TO THE ASSUMED DISCORDANCE OF THE ANCIENT AND MODERN CAUSES OF CHANGE.

On the causes of vicissitudes in climate — Remarks on the present diffusion of heat over the globe — On the dependence of the mean temperature on the relative position of land and sea — Isothermal lines — Currents from equatorial regions — Drifting of icebergs — Different temperature of Northern and Southern hemispheres — Combination of causes which might produce the extreme cold of which the earth's surface is susceptible — Conditions necessary for the production of the extreme of heat, and its probable effects on organic life.

Causes of vicissitudes in climate. — As the proofs enumerated in the last chapter indicate that the earth's surface has experienced great changes of climate since the deposition of the older sedimentary strata, we have next to inquire, how such vicissitudes can be reconciled with the existing order of nature. The cosmogonist has availed himself of this, as of every obscure problem in geology, to confirm his views concerning a period when the laws of the animate and inanimate world differed essentially from those now established ; and he has in this, as in many other cases, succeeded so far, as to divert attention from that class of facts, which, if fully understood, might probably lead to an explanation of the phenomena. At first it was imagined that the earth's axis had been for ages perpendicular to the plane of the ecliptic, so that there was a

perpetual equinox, and uniformity of seasons throughout the year ;— that the planet enjoyed this “paradisiacal” state until the era of the great flood ; but in that catastrophe, whether by the shock of a comet, or some other convulsion, it lost its equal poise, and hence the obliquity of its axis, and with that the varied seasons of the temperate zone, and the long nights and days of the polar circles.

When the progress of astronomical science had exploded this theory, it was assumed, that the earth at its creation was in a state of fluidity, and red hot, and that ever since that era it had been cooling down, contracting its dimensions, and acquiring a solid crust, — an hypothesis hardly less arbitrary, yet more calculated for lasting popularity, because, by referring the mind directly to the beginning of things, it requires no support from observation, nor from any ulterior hypothesis. But if, instead of forming vague conjectures as to what might have been the state of the planet at the era of its creation, we fix our thoughts on the connexion at present existing between climate and the distribution of land and sea ; and then consider what influence former fluctuations in the physical geography of the earth must have had on superficial temperature, we may perhaps approximate to a true theory. If doubts and obscurities still remain, they should be ascribed to our limited acquaintance with the laws of Nature, not to revolutions in her economy ; — they should stimulate us to further research, not tempt us to indulge our fancies respecting the imaginary changes of internal temperature in an embryo world.

Diffusion of heat over the globe. — In considering the laws which regulate the diffusion of heat over the

globe, we must be careful, as Humboldt well remarks, not to regard the climate of Europe as a type of the temperature which all countries placed under the same latitude enjoy. The physical sciences, observes this philosopher, always bear the impress of the places where they began to be cultivated; and as, in geology, an attempt was at first made to refer all the volcanic phenomena to those of the volcanos in Italy, so, in meteorology, a small part of the old world, the centre of the primitive civilization of Europe, was for a long time considered a type to which the climate of all corresponding latitudes might be referred. But this region, constituting only one seventh of the whole globe, proved eventually to be the exception to the general rule. For the same reason, we may warn the geologist to be on his guard, and not hastily to assume that the temperature of the earth in the present era is a type of that which most usually obtains, since he contemplates far mightier alterations in the position of land and sea, at different epochs, than those which now cause the climate of Europe to differ from that of other countries in the same parallels.

It is now well ascertained that zones of equal warmth, both in the atmosphere and in the waters of the ocean, are neither parallel to the equator nor to each other.* It is also known that the *mean annual*

* We are indebted to Baron Alex. Humboldt for collecting together, in a beautiful essay, the scattered data on which he founded an approximation to a true theory of the distribution of heat over the globe. Many of these data are derived from the author's own observations, and many from the works of M. Pierre Prevost, of Geneva, on the radiation of heat, and other writers. — See Humboldt on Isothermal Lines, *Mémoire d'Accueil*, tom. iii. translated in the Edin. Phil. Journ. vol. iii. July, 1820.

temperature may be the same in two places which enjoy very different climates, for the seasons may be nearly uniform, or violently contrasted, so that the lines of equal winter temperature do not coincide with those of equal annual heat, or isothermal lines. The deviations of all these lines from the same parallel of latitude are determined by a multitude of circumstances, among the principal of which are the position, direction, and elevation of the continents and islands, the position and depths of the sea, and the direction of currents and of winds.

On comparing the two continents of Europe and America, it is found that places in the same latitudes have sometimes a mean difference of temperature amounting to 11° , or even in a few cases to 17° Fahr.; and some places on the two continents, which have the same mean temperature, differ from 7° to 13° in latitude.* The principal cause of greater intensity of cold in corresponding latitudes of North America and Europe, is the connexion of North America with the polar circle, by a large tract of land, some of which is from three to five thousand feet in height, and, on the other hand, the separation of Europe from the arctic circle by an ocean. The ocean has a tendency to preserve every where a mean temperature, which it communicates to the contiguous land, so that it tempers the climate, moderating alike an excess of heat or cold. The elevated land, on the other hand, rising to the colder regions of the atmosphere becomes a great reservoir of ice and snow, arrests, condenses, and congeals vapour, and communicates its cold to the adjoining country. For this reason, Greenlaad, forming part

* Humboldt's tables, *Essay on Isothermal Lines, &c.*

of a continent, which stretches northward to the 82d degree of latitude, experiences under the 60th parallel a more rigorous climate than Lapland under the 72d parallel.

But if land be situated between the 40th parallel and the equator, it produces, unless it be of extreme height, exactly the opposite effect; for it then warms the tracts of land or sea that intervene between it and the polar circle. For the surface being in this case exposed to the vertical, or nearly vertical rays of the sun, absorbs a large quantity of heat, which it diffuses by radiation into the atmosphere. For this reason, the western parts of the old continent derive warmth from Africa, "which, like an immense furnace, distributes its heat to Arabia, to Turkey in Asia, and to Europe." * On the contrary, the north-eastern extremity of Asia experiences in the same latitude extreme cold; for it has land on the north between the 60th and 70th parallel, while to the south it is separated from the equator by the Pacific Ocean.

In consequence of the more equal temperature of the waters of the ocean, the climate of islands and of coasts differs essentially from that of the interior of continents, the more maritime climates being characterized by mild winters and more temperate summers; for the sea breezes moderate the cold of winter, as well as the heat of summer. When, therefore, we trace round the globe those belts in which the mean annual temperature is the same, we often find great differences in climate; for there are *insular* climates in which the seasons are nearly equalized, and *excessive* climates, as they have been termed, where the

* Malte-Brun. Phys. Geog. book xvii.

temperature of winter and summer is strongly contrasted. The whole of Europe, compared with the eastern parts of America and Asia, has an insular climate. The northern part of China, and the Atlantic region of the United States, exhibit "excessive climates." We find at New York, says Humboldt, the summer of Rome and the winter of Copenhagen; at Quebec, the summer of Paris and the winter of Petersburg. At Pekin, in China, where the mean temperature of the year is that of the coasts of Brittany, the scorching heats of summer are greater than at Cairo, and the winters as rigorous as at Upsala.*

If lines be drawn round the globe through all those places which have the same winter temperature, they are found to deviate from the terrestrial parallels much farther than the lines of equal mean annual heat. The lines of equal winter in Europe, for example, are often curved so as to reach parallels of latitude 9° or 10° distant from each other, whereas the isothermal lines, or those passing through places having the same mean annual temperature, differ only from 4° to 5° in Europe.

Influence of currents and drift ice on temperature.—Among other influential causes, both of remarkable diversity in the mean annual heat, and of unequal division of heat in the different seasons, are the direction of currents and the accumulation and drifting of ice in high latitudes. The temperature of the Lagullas current is 10° or 12° Fahr. above that of the sea at the Cape of Good Hope; for it derives the greater part of its waters from the Mozambique channel, and south-east coast of Africa, and from regions in the

* On Isothermal Lines, &c.

Indian Ocean much nearer the line, and much hotter than the Cape.* An opposite effect is produced by the "equatorial" current, which crosses the Atlantic from Africa to Brazil, having a breadth varying from 160 to 450 nautical miles. Its waters are cooler by 3° or 4° Fahr. than those of the ocean under the line, so that it moderates the heat of the tropics. †

But the effects of the Gulf stream on the climate of the north Atlantic Ocean are far more remarkable. This most powerful of known currents has its source in the Gulf or Sea of Mexico, which, like the Mediterranean and other close seas in temperate or low latitudes, is warmer than the open ocean in the same parallels. The temperature of the Mexican sea in summer is, according to Rennell, 86° Fahr. or at least 7° above that of the Atlantic in the same latitude.‡ From this great reservoir or caldron of warm water, a constant current pours forth through the straits of Bahama at the rate of 3 or 4 miles an hour; it crosses the ocean in a north-easterly direction, skirting the great bank of Newfoundland, where it still retains a temperature of 8° above that of the surrounding sea. It reaches the Azores in about 78 days, after flowing nearly 3000 geographical miles, and from thence it sometimes extends its course a thousand miles further, so as to reach the Bay of Biscay, still retaining an excess of 5° above the mean temperature of that sea. As it has been known to arrive there in the months of November and January, it may tend greatly to moderate the cold of winter in countries on the west of Europe.

There is a large tract in the centre of the North

* Rennell on Currents, p. 96. London, 1832.

† Ibid. p. 153.

‡ Ibid. p. 25.

Atlantic, between the parallels of 33° and 35° N. lat. which Rennell calls the "recipient of the gulf water." A great part of it is covered by the weed called sargasso (*Lentiula marina*), which the current floats in abundance from the Gulf of Mexico. This mass of water is nearly stagnant, is warmer by 7° or 10° than the waters of the Atlantic, and may be compared to the fresh water of a river overflowing the heavier salt water of the sea. Rennell estimates the area of the "recipient," together with that covered by the main current, as being 2000 miles in length from E. to W., and 350 in breadth from N. to S., which, he remarks, is a larger area than that of the Mediterranean. The heat of this great body of water is kept up by the incessant and quick arrivals of fresh supplies of warm water from the south, and there can be no doubt that the general climate of parts of Europe and America are materially affected by this cause.

It is considered probable by Scoresby, that the influence of the gulf stream extends even to the sea near Spitzbergen, where its waters may pass under those of melted ice; for it has been found that, in the neighbourhood of Spitzbergen, the water is warmer by 6° or 7° at the depth of one hundred and two hundred fathoms than at the surface. This might arise from the known law that fresh water passes the point of greatest density when cooled down below 40° , and between that and the freezing point expands again. The water of melted ice might be lighter, both as being fresh (having lost its salt in the decomposing process of freezing), and because its temperature is nearer the freezing point than the inferior water of the gulf stream.*

* When Scoresby wrote in 1820 (*Arctic Regions*, vol. i.

The great glaciers generated in the valleys of Spitzbergen, in the 79° of north latitude, are almost all cut off at the beach, being melted by the feeble remnant of heat still retained by the gulf stream. In Baffin's Bay, on the contrary, on the west coast of Old Greenland, where the temperature of the sea is not mitigated by the same cause, and where there is no warmer under-current, the glaciers stretch out from the shore, and furnish repeated crops of mountainous masses of ice which float off into the ocean.* The number and dimensions of these bergs is prodigious. Captain Ross saw several of them together in Baffin's Bay aground in water fifteen hundred feet deep! Many of them are driven down into Hudson's Bay, and accumulating there, diffuse excessive cold over the neighbouring continent; so that Captain Franklin reports, that at the mouth of Hayes river, which lies in the same latitude as the north of Prussia or the south of Scotland, ice is found every where in digging wells, in summer, at the depth of four feet! Other bergs have been occasionally met with, at midsummer, in a state

p. 210.), he doubted whether salt water expanded like fresh water when freezing. Since that time Erman (*Poggendorf's Annalen*, 1828, vol. xii. p. 483.) has proved by experiment that sea-water does not follow the same law as fresh water, as De Luc, Rumford, and Marcey had supposed. On the contrary, it appears that salt water of sp. gr. 1.027 (which according to Berzelius is the mean density of sea water) has *no maximum of density* so long as it remains fluid; and even when ice begins to form in it, the remaining fluid part always increases in density in proportion to the degree of refrigeration.

* Scoresby's *Arctic Regions*, vol. i. p. 208. — Dr. Latta's Observations on the Glaciers of Spitzbergen, &c. Edin. New Phil. Journ. vol. iii. p. 97.

of rapid thaw, as far south as lat. 40° , and longitude about 60° West, where they cool the water sensibly to the distance of forty or fifty miles around, the thermometer sinking sometimes 17° , or even 18° , Fahrenheit, in their neighbourhood.* It is a well-known fact that every four or five years a large number of icebergs, floating from Greenland, double Cape Langaness, and are stranded on the west coast of Iceland. The inhabitants are then aware that their crops will fail, in consequence of fogs which are generated almost incessantly; and the dearth of food is not confined to the land, for the temperature of the water is so changed that the fish entirely desert the coast.

Difference of climate of the Northern and Southern hemispheres. — When we compare the climate of the northern and southern hemispheres, we obtain still more instruction in regard to the influence of the distribution of land and sea on climate. The dry land in the southern hemisphere is to that of the northern in the ratio only of one to three, excluding from our consideration that part which lies between the pole and the 74° of south latitude, which has hitherto proved inaccessible. And whereas, in the northern hemisphere, between the pole and the thirtieth parallel of north latitude, the land and sea occupy nearly equal areas, the ocean in the southern hemisphere covers no less than fifteen parts in sixteen of the entire space included between the antarctic circle and the thirtieth parallel of south latitude.

This great extent of sea gives a particular character to climates south of the equator, the winters being mild and the summers cool. Thus, in Van Diemen's

* Rennell on Currents, p. 95.

Land, corresponding nearly in latitude to Rome, the winters are more mild than at Naples, and the summers not warmer than those at Paris, which is 7° farther from the equator.* The effects on animal and vegetable life are remarkable. Capt. King observed large shrubs of Fuchsia and Veronica, which in England are treated as tender plants, thriving and in full flower in Terra del Fuego with the temperature at 36° . He states also that humming birds were seen sipping the sweets of the flowers "after two or three days of constant rain, snow, and sleet, during which time the thermometer had been at the freezing point." Mr. Darwin also saw parrots feeding on the seeds of a tree called the winter's bark, south of lat. 55° near Cape Horn.†

So the orchideous plants which are parasitical on trees, and are generally characteristic of the tropics, advance to the 38th and 42d degree of S. lat., and even beyond the 45th degree in New Zealand, where they were found by Forster. In South America also, arborescent grasses abound in the dense forests of Chiloe, in lat. 42° S., where "they entwine the trees into one entangled mass to the height of thirty or forty feet above the ground. Palm trees in the same quarter of the globe grow in lat. 37° , and an arborescent grass very like a bamboo in 40° , and another closely allied kind, of great length, but not erect, even as far south as 45° ."‡

It has long been supposed that the general temperature of the southern hemisphere was considerably lower than that of the northern, and that the difference

* Humboldt on Isothermal Lines.

† Journ. of Travels in S. America, &c. p. 272.

‡ Darwin, ibid. p. 271.

amounted to at least 10° Fahrenheit. Baron Humboldt, after collecting and comparing a great number of observations, came to the conclusion that even a much larger difference existed, but that none was to be observed within the tropics, and only a small difference as far as the thirty-fifth and fortieth parallel. Captain Cook was of opinion that the ice of the antarctic predominated greatly over that of the arctic region, that encircling the southern pole coming nearer to the equator by 10° than the ice around the north pole. But the recent voyages of Weddell and Biscoe have shown that on certain meridians it is possible to approach the south pole nearer by several degrees than Cook had penetrated; and even in the seventy-third and seventy-fourth degrees of south latitude, they found the sea open and with few ice-floes.*

Nevertheless, the greater cold of high southern latitudes is confirmed by the description given both by ancient and modern navigators of the lands in this hemisphere. In Sandwich land, in lat. 59° S., or in the same parallel as the north of Scotland, Capt. Cook found the whole country, from the summits of the mountains down to the very brink of the sea-cliffs, "covered many fathoms thick with everlasting snow,"

* Captain Weddell, in 1823, advanced 8° farther than Captain Cook, and arrived at lat. $74^{\circ} 15'$ south, long. $34^{\circ} 17'$ west. After having passed through a sea strewed with numerous ice islands, he arrived, in that high latitude, at an open ocean; but even if he had sailed 6° farther south, he would not have penetrated to higher latitudes than Captain Parry in the arctic circle, who reached lat. $81^{\circ} 12' 51''$ north. Captain Biscoe, in 1831 and 1832, discovered Graham's Land, between 64° and 68° S. lat., to the southward of New South Shetland, and Enderby's Land, in the same latitude, on the meridian of Madagascar. Journ. of Roy. Geograph. Soc. of London, 1833, p. 105.

and this on the 1st of February, the hottest time of the year; and what is still more astonishing, in the island of Georgia, which is in the 54° south latitude, or the same parallel as Yorkshire, the line of perpetual snow descends to the level of the ocean. When we consider this fact, and then recollect that the highest mountains in Scotland, which ascend to an elevation of nearly 5000 feet, and are four degrees farther to the north, do not attain the limit of perpetual snow on our side of the equator, we learn that latitude is one only, of many powerful causes, which determine the climate of particular regions of the globe. The permanence of snow in the southern hemisphere, is in this instance partly due to the floating ice, which chills the atmosphere and condenses the vapour, so that in summer the sun cannot pierce through the foggy air. But besides the abundance of ice which covers the sea to the south of Georgia and Sandwich land, we may also, as Humboldt suggests, ascribe the cold of those countries in part to the absence of land between them and the tropics.

If Africa and New Holland extended farther to the south, a diminution of ice would take place in consequence of the radiation of heat from these continents during summer, which would warm the contiguous sea and rarefy the air. The heated aerial currents would then ascend and flow more rapidly towards the south pole, and moderate the winter. In confirmation of these views, it is stated that the ice, which extends as far as the 68° and 71° of south latitude, advances more towards the equator whenever it meets an open sea; that is, where the extremities of the present continents are not opposite to it; and this circumstance seems explicable only on the principle above

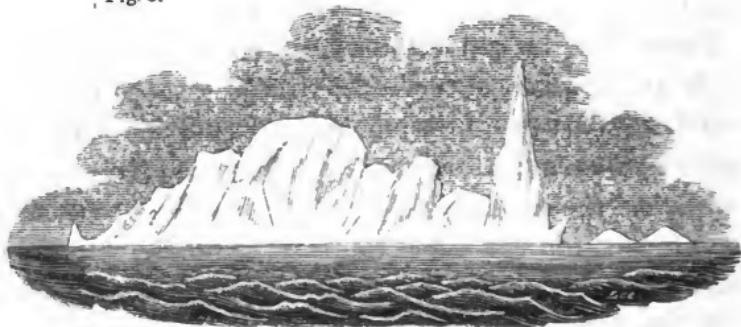
alluded to, of the radiation of heat from the lands so situated.

The cold of the antarctic regions was conjectured by Cook to be due to the existence of a large tract of land between the seventieth degree of south latitude and the pole; and it is worthy of observation, that even now, after the most recent voyages, the area still unexplored within the antarctic circle is much more than double the area of Europe.* Some geographers think that the late discovery of Graham's and Enderby's Lands (between lat. 64° and 68° S.), both of which Captain Biscoe believes to be of great extent, has strengthened the probability of Cook's conjecture. These newly observed countries, although placed in latitudes in which herds of wild herbivorous animals are met with in the northern hemisphere, nay, where man himself exists, and where there are ports and villages, are described as most wintry in their aspect, almost entirely covered, even in summer, with ice and snow, and nearly destitute of animal life.

The distance to which icebergs float from the polar regions on the opposite sides of the line is, as might have been anticipated, very different. Their extreme limit in the northern hemisphere is lat. 40° , as before mentioned, and they are occasionally seen in lat. 42° N. near the termination of the great bank of Newfoundland, and at the Azores, lat. 42° N., to which they are sometimes drifted from Baffin's Bay. But in the other hemisphere they have been seen, within the last few years, at different points off the Cape of Good Hope,

* Mr. Gardner informs me that the surface of Europe contains about 2,795,000 square geographical miles, the unexplored antarctic region about 7,620,000.

Fig. 3.



*Iceberg seen off the Cape of Good Hope, April, 1829.
Lat. 39° 13' S. Long. 48° 46' E.*

between lat. 36° and 39° .* One of these (see fig. 3.) was two miles in circumference, and 150 feet high, appearing like chalk when the sun was obscured, and having the lustre of refined sugar when the sun was shining on it. Others rose from 250 to 300 feet above the level of the sea, and were therefore of great volume below ; since it is ascertained, by experiments on the buoyancy of ice floating in sea-water, that for every cubic foot seen above, there must at least be eight cubic feet below water.† If ice islands from the north polar regions floated as far, they might reach Cape St. Vincent, and there, being drawn by the current that always sets in from the Atlantic through the Straits of Gibraltar, be drifted into the Mediterranean, so that the serene sky of that delightful region might soon be deformed by clouds and mists.

Before the amount of difference between the temperature of the two hemispheres was ascertained, it was referred by many astronomers to the precession of

* On Icebergs in low Latitudes, by Capt. Horsburgh, by whom the sketch was made. Phil. Trans. 1830.

† Scoresby's Arctic Regions, vol. i. p. 234.

the equinoxes, or the acceleration of the earth's motion in its perihelium ; in consequence of which the spring and summer of the southern hemisphere are now shorter, by nearly eight days, than those seasons north of the equator. But Sir J. Herschel reminds us that the excess of eight days in the duration of the sun's presence in the northern hemisphere is not productive of an excess of annual light and heat ; since, according to the laws of elliptic motion, it is demonstrable that whatever be the ellipticity of the earth's orbit, the two hemispheres must receive *equal absolute quantities* of light and heat per annum, the proximity of the sun in perigee exactly compensating the effect of its swifter motion.* Humboldt, however, observes, that there must be a greater loss of heat by radiation in the southern hemisphere during a winter longer by eight days than that on the other side of the equator.†

Perhaps no very sensible effect may be produced by this source of disturbance, yet the geologist should bear in mind that to a certain extent it operates alternately on each of the two hemispheres for a period of upwards of 10,000 years, dividing unequally the times during which the annual supply of solar light and heat is received. This cause may sometimes tend to counterbalance inequalities of temperature resulting from other

* This follows, observes Herschel, from a very simple theorem, which may be thus stated : — “ The amount of heat received by the earth from the sun, while describing any part of its orbit, is proportional to the angle described round the sun's centre.” So that if the orbit be divided into two portions by a line drawn in any direction through the sun's centre, the heat received in describing the two unequal segments of the ellipse so produced will be equal. Geol. Trans. vol. iii. part. ii. p. 298. ; second series.

† On Isothermal Lines.

far more influential circumstances; but, on the other hand, it must sometimes tend to increase the extreme of deviation arising from particular combinations of causes.

But whatever may be at present the inferiority of heat in the temperate and frigid zones south of the line, it is quite evident that the cold would be far more intense if there happened, instead of open sea, to be tracts of elevated land between the 55th and 70th parallel; and on the other hand, the cold would be moderated if there was more land between the line and the forty-fifth degree of south latitude.

Changes in the position of land and sea may give rise to vicissitudes in climate.—Having offered these brief remarks on the diffusion of heat over the globe in the present state of the surface, I shall now proceed to speculate on the vicissitudes of climate, which must attend those endless variations in the geographical features of our planet which are contemplated in geology. That our speculations may be confined within the strict limits of analogy, I shall assume, 1st, That the proportion of dry land to sea continues always the same. 2dly, That the volume of the land rising above the level of the sea is a constant quantity; and not only that its mean, but that its extreme height, are liable only to trifling variations. 3dly, That both the mean and extreme depth of the sea are invariable; and, 4thly, It may be consistent with due caution to assume that the grouping together of the land in great continents is a necessary part of the economy of nature; for it is possible that the laws which govern the subterranean forces, and which act simultaneously along certain lines, cannot but produce, at every epoch, continuous mountain-chains; so that the subdivision

of the whole land into innumerable islands may be precluded.

If it be objected, that the maximum of elevation of land and depth of sea are probably not constant, nor the gathering together of all the land in certain parts, nor even perhaps the relative extent of land and water, I reply, that the arguments about to be adduced will be strengthened, if, in these peculiarities of the surface, there be considerable deviations from the present type. If, for example, all other circumstances being the same, the land is at one time more divided into islands than at another, a greater uniformity of climate might be produced, the mean temperature remaining unaltered ; or if, at another era, there were mountains higher than the Himalaya, these, when placed in high latitudes, would cause a greater excess of cold. Or, if we suppose that at certain periods no chain of hills in the world rose beyond the height of 10,000 feet, a greater heat might then have prevailed than is compatible with the existence of mountains thrice that elevation.

However constant may be the relative proportion of sea and land, we know that there is annually some small variation in their respective geographical positions, and that in every century the land is in some parts raised, and in others depressed by earthquakes ; and so likewise is the bed of the sea. By these and other ceaseless changes, the configuration of the earth's surface has been remodelled again and again since it was the habitation of organic beings, and the bed of the ocean has been lifted up to the height of some of the loftiest mountains. The imagination is apt to take alarm when called upon to admit the formation of such irregularities in the crust of the earth, after it had once become the habitation of living crea-

tures ; but, if time be allowed, the operation need not subvert the ordinary repose of nature, and the result is in a general view insignificant if we consider how slightly the highest mountain-chains cause our globe to differ from a perfect sphere. Chimborazo, though it rises to more than 21,000 feet above the sea, would be represented, on a globe of about six feet in diameter, by a grain of sand less than one twentieth of an inch in thickness.*

The superficial inequalities of the earth, then, may be deemed minute in quantity, and their distribution at any particular epoch must be regarded in geology as temporary peculiarities, like the height and outline of the cone of Vesuvius in the interval between two eruptions. But although, in reference to the magnitude of the globe, the unevenness of the surface is so unimportant, it is on the position and direction of these small inequalities that the state of the atmosphere, and both the local and general climate, are mainly dependent.

Before considering the effect which a material change in the distribution of land and sea must occasion, it may be well to remark, how greatly organic life may be affected by those minor variations, which need not in the least degree alter the general temperature. Thus, for example, if we suppose, by a series of convulsions, a certain part of Greenland to become sea, and, in compensation, a tract of land to rise and connect Spitzbergen with Lapland,—an accession not greater in amount than one which the geologist can prove to have occurred in certain districts bordering the Mediterranean, within a com-

* Malte-Brun's System of Geography, book i. p. 6.

paratively modern period,—this altered form of the land might cause an interchange between the climate of certain parts of North America and of Europe, which lie in corresponding latitudes. Many European species of plants and animals would probably perish in consequence, because the mean temperature would be greatly lowered; and others would fail in America, because it would there be raised. On the other hand, in places where the mean annual heat remained unaltered, some species which flourish in Europe, where the seasons are more uniform, would be unable to resist the greater heat of the North American summer, or the intenser cold of the winter; while others, now fitted by their habits for the great contrast of the American seasons, would not be fitted for the *insular* climate of Europe. The vine, for example, according to Humboldt, can be cultivated with advantage 10° farther north in Europe than in North America. Many plants endure severe frost, but cannot ripen their seeds without a certain intensity of summer heat and a certain quantity of light; others cannot endure a similar intensity either of heat or cold.

It is now established that many of the existing species of animals have survived great changes in the physical geography of the globe. If such species be termed modern, in comparison to races which preceded them, their remains, nevertheless, enter into submarine deposits many hundred miles in length, and which have since been raised from the deep to no inconsiderable altitude. When, therefore, it is shown that changes in the temperature of the atmosphere may be the consequence of such physical revolutions of the surface, we ought no longer to wonder that we find the distribution of existing species to be *local*, in

regard to *longitude* as well as latitude. If all species were now, by an exertion of creative power, to be diffused uniformly throughout those zones where there is an equal degree of heat, and in all respects a similarity of climate, they would begin from this moment to depart more and more from their original distribution. Aquatic and terrestrial species would be displaced, as Hooke long ago observed, so often as land and water exchanged places; and there would also, by the formation of new mountains and other changes, be transpositions of climate, contributing, in the manner before alluded to, to the local extermination of species.*

If we now proceed to consider the circumstances required for a *general* change of temperature, it will appear, from the facts and principles already laid down, that whenever a greater extent of high land is collected in the polar regions, the cold will augment; and the same result will be produced when there is more sea between or near the tropics; while, on the contrary, so often as the above conditions are reversed, the heat will be greater. (See Map, Pl. 2.) If this be admitted, it will follow, that unless the superficial inequalities of the earth be fixed and permanent, there must be never-ending fluctuations in the mean temperature of every zone; and that the climate of one era can no more be a type of every other, than is one of our four seasons of all the rest.

It has been well said, that the earth is covered by an ocean, in the midst of which are two great islands, and many smaller ones; for the whole of the conti-

* A full consideration of the effect of changes in physical geography on the distribution and extinction of species, is given in book iii.

nents and islands occupy an area scarcely exceeding one fourth of the whole superficies of the spheroid. Now, on a fair estimate of probability, we may reasonably assume that there will not, at any given epoch, be more than about one fourth dry land in a particular region ; such, for example, as within the arctic and antarctic circles. If, therefore, at present there should happen, in the only one of these regions which we can explore, to be much *more* than this average proportion of land, and some of it above five thousand feet in height, this alone affords ground for concluding that, in the present state of things, the mean heat of the climate is below that which the earth's surface, in its more ordinary state, would enjoy. This presumption would be heightened, were we to assume that the mean depth of the Atlantic and Pacific oceans is as great as some astronomers have imagined * ; for then

* See Young's Nat. Phil., Lect. xlvii. ; Mrs. Somerville's Connex. of Phys. Sci., sect. 14. p. 110. Laplace, endeavouring to estimate the probable depth of the sea from some of the phenomena of the tides, says of the ocean generally, "que sa profondeur moyenne est du même ordre que la hauteur moyenne des continens et des îles au-dessus de son niveau, hauteur qui ne surpasse pas mille mètres (3280 ft.)." Mec. Céleste, Bk. xi. et Syst. du Monde, p. 254. The expression "du même ordre" admits in mathematical language of considerable latitude of signification, and does not mean that the depth of the water below the level of the sea corresponds exactly to the height of the land above it. I have endeavoured, in vain, after consulting several eminent mathematicians, among others, Professor Airy, Mr. Lubbock, and Mr. Whewell, to arrive at some conclusion as to the absolute depth of the ocean. My informants all agree in declaring that the hypothetical data on which the calculations of Laplace necessarily proceeded cannot give even an approximation to a solution of the problem. Neither does Mr. Whewell believe in the alleged

we might look not only for more than two thirds sea in the frigid zones, but for water of great depth, which could not readily be reduced to the freezing point. The same opinion is confirmed, when we compare the quantity of land lying between the poles and the 30th parallels of north and south latitude, with the quantity placed between those parallels and the equator; for, it is clear, that we have at present not only more than the usual degree of cold in the polar regions, but also less than the average quantity of heat within the tropics.

Position of land and sea which might produce the extreme of cold of which the earth's surface is susceptible. — To simplify our view of the various changes in climate, which different combinations of geographical circumstances may produce, we shall first consider the conditions necessary for bringing about the extreme of cold, or what may be termed the winter of the "great year," or geological cycle, and afterwards, the conditions requisite to produce the maximum of heat, or the summer of the same year.

To begin with the northern hemisphere. Let us suppose those hills of the Italian peninsula and of Sicily, which are of comparatively modern origin, and contain many fossil shells identical with living species, to subside again into the sea, from which they have been raised, and that an extent of land of equal area and height (varying from one to three thousand feet) should rise up in the Arctic Ocean between Siberia

approach to uniformity in the depth of the ocean, which some have wished to deduce from the supposed smallness of the difference of the two tides occurring on the same day. (London, March, 1835.)

and the north pole. In speaking of such changes, I shall not allude to the manner in which I conceive it possible that they may be brought about, nor of the time required for their accomplishment — reserving for a future occasion, not only the proofs that revolutions of equal magnitude have taken place, but that analogous operations are still in gradual progress. The alteration now supposed in the physical geography of the northern regions would cause additional snow and ice to accumulate where now there is usually an open sea ; and the temperature of the greater part of Europe would be somewhat lowered, so as to resemble more nearly that of corresponding latitudes of North America : or, in other words, it might be necessary to travel about 10° farther south in order to meet with the same climate which we now enjoy. No compensation would be derived from the disappearance of land in the Mediterranean countries ; but the contrary, since the mean heat of the soil in those latitudes is probably far above that which would belong to the sea, by which we imagine it to be replaced.

But let the configuration of the surface be still further varied, and let some large district within or near the tropics, such as Brazil, with its plains and hills of moderate height, be converted into sea, while lands of equal elevation and extent rise up in the arctic circle. From this change there would, in the first place, result a sensible diminution of temperature near the tropic, for the Brazilian soil would no longer be heated by the sun ; so that the atmosphere would be less warm, as also the neighbouring Atlantic. On the other hand, the whole of Europe, Northern Asia, and North America, would be chilled by the enormous quantity of ice and snow, thus generated on the new

arctic continent. If, as we have already seen, there are now some points in the southern hemisphere where snow is perpetual down to the level of the sea, in latitudes as low as central England, such might assuredly be the case throughout a great part of Europe, under the change of circumstances above supposed; and if at present the extreme range of drifted icebergs is the Azores, they might easily reach the equator after the assumed alteration. But to pursue the subject still farther, let the Himalaya mountains, with the whole of Hindostan, sink down, and their place be occupied by the Indian ocean, while an equal extent of territory and mountains, of the same vast height, rise up between North Greenland and the Orkney islands. It seems difficult to exaggerate the amount to which the climate of the northern hemisphere would then be cooled.

But the refrigeration brought about at the same time in the southern hemisphere, would be nearly equal, and the difference of temperature between the arctic and equatorial latitudes would not be much greater than at present; for no important disturbance can occur in the climate of a particular region, without its immediately affecting all other latitudes, however remote. The heat and cold which surround the globe are in a state of constant and universal flux and reflux. The heated and rarefied air is always rising and flowing from the equator towards the poles in the higher regions of the atmosphere; while in the lower, the colder air is flowing back to restore the equilibrium. That this circulation is constantly going on in the aerial currents is not disputed; it is often proved by the opposite course of the clouds at different heights, and the fact has been farther illustrated in a striking

manner by two recent events. The trade wind continually blows with great force from the island of Barbadoes to that of St. Vincent; notwithstanding which, during the eruption of the volcano in the island of St. Vincent, in 1812, ashes fell in profusion from a great height in the atmosphere upon Barbadoes.* In like manner, during the great eruption of Sumbawa, in 1815, ashes were carried to the islands of Amboyna and Banda, which last is about 800 miles east from the site of the volcano. Yet the south-east monsoon was then at its height.† This apparent transportation of matter against the wind, confirmed the opinion of the existence of a counter-current in the higher regions, which had previously rested on theoretical conclusions only.

That a corresponding interchange takes place in the seas, is demonstrated, according to Humboldt, by the cold which is found to exist at great depths between the tropics; and, among other proofs, may be mentioned the mass of warmer water which the Gulf stream is constantly bearing northwards, while a cooler current flows *from* the north along the coast of Greenland and Labrador, and helps to restore the equilibrium.‡

Currents of heavier and colder water pass from the poles towards the equator, which cool the inferior

* Daniell's Meteorological Essays, p. 103.

† Observed by J. Crawfurd, Esq.

‡ In speaking of the circulation of air and water in this chapter, no allusion is made to the trade winds, or to irregularities in the direction of currents, caused by the rotatory motion of the earth. These causes prevent the movements from being direct from north to south, or from south to north, but they do not affect the theory of a constant circulation.

parts of the ocean *; so that the heat of the torrid zone and the cold of the polar circle balance each other. The refrigeration, therefore, of the polar regions, resulting from the supposed alteration in the distribution of land and sea, would be immediately communicated to the tropics, and from them its influence would extend to the antarctic circle, where the atmosphere and the ocean would be cooled, so that ice and snow would augment. Although the mean temperature of higher latitudes in the southern hemisphere is, as before stated, for the most part lower than that of the same parallels in the northern, yet, for a considerable space on each side of the line, the mean annual heat of the waters is found to be the same in corresponding parallels. If, therefore, by the new position of the land, the formation of icebergs had become of common occurrence in the northern temperate zone, and if these were frequently drifted as far as the equator, the same degree of cold which they generated would immediately be communicated as far as the tropic of Capricorn, and from thence to the lands or ocean to the south.

The freedom, then, of the circulation of heat and cold from pole to pole being duly considered, it will be evident that the mean temperature which may prevail at the same point at two distinct periods, may differ far more widely than that of any two points in the same parallels of latitude, at one and the same period. For the range of temperature, or, in other words, the curvature of the isothermal lines in a given zone, and at a given period, must always be circumscribed within

* See note, p. 168., on the increasing density of sea-water in proportion to the degree of cold.

narrow limits, the climate of each place in that zone being controlled by the combined influence of the geographical peculiarities of all other parts of the earth. Whereas, if we compare the state of things at two distinct and somewhat distant epochs, a particular zone may at one time be under the influence of one class of disturbing causes, and at another time may be affected by an opposite combination. The lands, for example, to the north of Greenland cause the present climate of North America to be colder than that of Europe in the same latitudes ; but the excess of cold is not so great as it would have been if the western hemisphere had been entirely isolated, or separated from the eastern like a distinct planet. For not only does the refrigeration produced by Greenland chill to a certain extent the atmosphere of northern and western Europe, but the mild climate of Europe reacts also upon North America, and moderates the chilling influence of the adjoining polar lands.

To return to the state of the earth after the changes above supposed, we must not omit to dwell on the important effects to which a wide expanse of perpetual snow would give rise. It is probable that nearly the whole sea, from the poles to the parallels of 45° , would be frozen over ; for it is well known that the immediate proximity of land is not essential to the formation and increase of field ice, provided there be in some part of the same zone a sufficient quantity of glaciers generated on or near the land, to cool down the sea. Captain Scoresby, in his account of the arctic regions, observes, that when the sun's rays "fall upon the snow-clad surface of the ice or land, they are in a great measure reflected, without producing any material elevation of temperature ; but when they impinge on

the black exterior of a ship, the pitch on one side occasionally becomes fluid while ice is rapidly generated at the other." *

Now field ice is almost always covered with snow †; and thus not only land as extensive as our existing continents, but immense tracts of sea in the frigid and temperate zones, might present a solid surface covered with snow, and reflecting the sun's rays for the greater part of the year. Within the tropics, moreover, where the ocean now predominates, the sky would no longer be serene and clear, as in the present era; but masses of floating ice would cause quick condensations of vapour, so that fogs and clouds would deprive the vertical rays of the sun of half their power. The whole planet, therefore, would receive annually a smaller proportion of the solar influence, and the external crust would part, by radiation, with some of the heat which had been accumulated in it, during a different state of the surface. This heat would be dissipated in the spaces surrounding our atmosphere, which, according to the calculations of M. Fourier, have a temperature much inferior to that of freezing water.

After the geographical revolution above assumed, the climate of equinoctial lands might be brought at last to resemble that of the present temperate zone, or perhaps be far more wintery. They who should then inhabit such small isles and coral reefs as are now seen in the Indian ocean and South Pacific, would wonder that zoophytes of large dimensions had once been so prolific in their seas; or if, perchance, they found the wood and fruit of the cocoa-nut tree or the palm silicified by the waters of some ancient mineral

* See Scoresby's Arctic Regions, vol. i. p. 378. † Ib. p. 320.

spring, or incrusted with calcareous matter, they would muse on the revolutions which had annihilated such genera, and replaced them by the oak, the chestnut, and the pine. With equal admiration would they compare the skeletons of their small lizards with the bones of fossil alligators and crocodiles more than twenty feet in length, which, at a former epoch, had multiplied between the tropics : and when they saw a pine included in an iceberg, drifted from latitudes which we now call temperate, they would be astonished at the proof thus afforded, that forests had once grown where nothing could be seen in their own times but a wilderness of snow.

If the reader hesitate to suppose so extensive an alteration of temperature as the probable consequence of geographical changes, confined to one hemisphere, he should remember how great are the local anomalies in climate now resulting from the peculiar distribution of land and sea in certain regions. Thus, in the island of South Georgia, before mentioned (p. 172.), Captain Cook found the everlasting snows descending to the level of the sea, between lat. 54° and 55° S.; no trees or shrubs were to be seen, and in summer a few rocks only, after a partial melting of the ice and snow, were scantily covered with moss and tufts of grass. If such a climate can now exist at the level of the sea in a latitude corresponding to that of Yorkshire, in spite of all those equalizing causes before enumerated, by which the mixture of the temperatures of distant regions is facilitated throughout the globe, what rigours might we not anticipate in a winter generated by the transfer of the mountains of India to our arctic circle!

But we have still to contemplate the additional

refrigeration which might be effected by changes in the relative position of land and sea in the southern hemisphere. If the remaining continents were transferred from the equatorial and contiguous latitudes to the south polar regions, the intensity of cold produced might, perhaps, render the globe uninhabitable. We are too ignorant of the laws governing the direction of subterranean forces, to determine whether such a crisis be within the limits of possibility. At the same time, it may be observed, that no distribution of land can well be imagined more irregular, or, as it were, capricious, than that which now prevails; for at present, the globe may be divided into two equal parts, in such a manner, that one hemisphere shall be almost entirely covered with water, while the other shall contain less water than land (See Map, Pl. 1.) *; and, what is still more extraordinary, on comparing the extratropical lands in the northern and southern hemispheres, the lands in the northern are found to be to those in the southern in the proportion of thirteen to one! † To imagine all the lands, therefore, in high, and all the

* This is shown by projecting a map on the horizon of London, that is to say, by supposing the eye of the observer to be placed above that city, and to see from thence one half of the globe. For it so happens that from that point, and no other, we should behold the greatest possible quantity of land, and if we are then transferred to the opposite or antipodal point, we should see the greatest possible quantity of water. (See Plate 1.) A singular fact, first pointed out by Mr. James Gardner, namely, that only one twenty-seventh part of the dry land has any land opposite to it, is intimately connected with this excess of land in one of the two hemispheres above alluded to. See Gardner, Geol. Soc. Proceedings, No. 32. p. 488.

† Humboldt on Isothermal Lines.

MAP shewing the present unequal distribution
of LAND & WATER on the surface of the GLOBE.



Fig. 1.

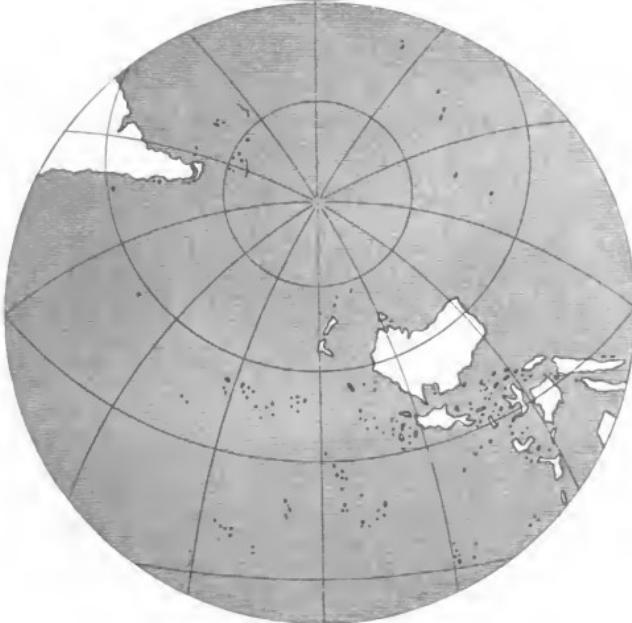


Fig. 2.

Fig. 1. Here London is taken as a centre and we behold the greatest quantity
of Land existing in one Hemisphere.

Fig. 2. Here the Centre is the Antipodal point to London and we see the
greatest quantity of Water existing in one Hemisphere.

M A P S
shewing the position
OF LAND AND SEA
which might produce the extremes of
HEAT AND COLD
in the Climates of the
G L O B E

Observations. These Maps are intended to shew that Continents & Islands having the same shape and relative dimensions as those now existing might be placed so as to occupy either the equatorial or polar regions

In Fig. N^o. 1 scarcely any of the land extends from the Equator towards the poles beyond the 30th parallel of Latitude and in Fig. 2. a very small proportion of it extends from the poles towards the Equator beyond the 40th parallel of Latitude.



sea in low latitudes, as delineated in the annexed plate (Pl. 2.), would scarcely be a more anomalous state of the surface.

Position of land and sea which might give rise to the extreme of heat.—Let us now turn from the contemplation of the winter of the “great year,” and consider the opposite train of circumstances which would bring on the spring and summer. To imagine all the lands to be collected together in equatorial latitudes, and a few promontories only to project beyond the thirtieth parallel, as represented in the annexed map (fig. 1. Pl. 2.), would be undoubtedly to suppose an extreme result of geological change. But if we consider a mere approximation to such a state of things, it would be sufficient to cause a general elevation of temperature. Nor can it be regarded as a visionary idea, that, amidst the revolutions of the earth’s surface, the quantity of land should, at certain periods, have been simultaneously lessened in the vicinity of both the poles, and increased within the tropics. We must recollect that even now it is necessary to ascend to the height of fifteen thousand feet in the Andes under the line, and in the Himalaya mountains, which are without the tropic, to seventeen thousand feet, before we reach the limit of perpetual snow. On the northern slope, indeed, of the Himalaya range, where the heat radiated from a great continent moderates the cold, there are meadows and cultivated land at an elevation equal to the height of Mont Blanc.* If then there were no arctic lands to chill the atmosphere, and freeze the sea, and if the loftiest chains were near the line, it

* Humboldt, *Tableaux de la Nature*, tom. i. p. 112.

seems reasonable to imagine that the highest mountains might be clothed with a rich vegetation to their summits, and that nearly all signs of frost would disappear from the earth.

When the absorption of the solar rays was in no region impeded, even in winter, by a coat of snow, the mean heat of the earth's crust would augment to considerable depths, and springs, which we know to be in general an index of the mean temperature of the climate, would be warmer in all latitudes. The waters of lakes, therefore, and rivers, would be much hotter in winter, and would be never chilled in summer by melted snow and ice. A remarkable uniformity of climate would prevail amid the archipelagos of the temperate and polar oceans, where the tepid waters of equatorial currents would freely circulate. The general humidity of the atmosphere would far exceed that of the present period, for increased heat would promote evaporation in all parts of the globe. The winds would be first heated in their passage over the tropical plains, and would then gather moisture from the surface of the deep, till, charged with vapour, they arrived at extreme northern and southern regions, and there encountering a cooler atmosphere, discharged their burden in warm rain. If, during the long night of a polar winter, the snows should whiten the summit of some arctic islands, they would be dissolved as rapidly by the returning sun, as are the snows of Etna by the blasts of the sirocco.

We learn from those who have studied the geographical distribution of plants, that in very low latitudes, at present, the vegetation of small islands remote from continents has a peculiar character; the ferns

and allied families, in particular, bearing a great proportion to the total number of other plants. Other circumstances being the same, the more remote the isles are from the continents, the greater does this proportion become. Thus, in the continent of India, and the tropical parts of New Holland, the proportion of ferns to the phænogamous plants is only as one to twenty-six; whereas, in the South-Sea Islands, it is as one to four, or even as one to three.*

We might expect, therefore, in the summer of the "great year," which we are now considering, that there would be a predominance of tree-ferns and plants allied to palms and arborescent grasses in the islands of the wide ocean, while the dicotyledonous plants and other forms now most common in temperate regions would almost disappear from the earth. Then might those genera of animals return, of which the memorials are preserved in the ancient rocks of our continents. The huge iguanodon might reappear in the woods, and the ichthyosaur in the sea, while the pterodactyle might fit again through umbrageous groves of tree-ferns. Coral reefs might be prolonged once more beyond the arctic circle, where the whale and the narwal now abound; and droves of turtles might wander again through regions now tenanted by the walrus and the seal.

But, not to indulge too far in these speculations, I may observe, in conclusion, that however great, during the lapse of ages, may be the vicissitudes of temperature in every zone, it accords with this theory that

* Ad. Brongniart, Consid. Générales sur la Nat. de la Végét. &c., Ann. des Sciences Nat., Nov. 1828.

the general climate should not experience any sensible change in the course of a few thousand years; because that period is insufficient to affect the leading features of the physical geography of the globe. Notwithstanding the apparent uncertainty of the seasons, it is found that the mean temperature of particular localities is very constant, when observations made for a sufficient series of years are compared.

Yet there must be exceptions to this rule; and even the labours of man have, by the drainage of lakes and marshes, and the felling of extensive forests, caused such changes in the atmosphere as greatly to raise our conception of the more important influence of those forces to which, in certain latitudes, even the existence of land or water, hill or valley, lake or sea, must be ascribed. If we possessed accurate information of the amount of *local* fluctuation in climate in the course of twenty centuries, it would often, undoubtedly, be considerable. Certain tracts, for example, on the coast of Holland and of England consisted of cultivated land in the time of the Romans, which the sea, by gradual encroachments, has at length occupied. Here, at least, a slight alteration has been effected; for neither the distribution of heat in the different seasons, nor the mean annual temperature of the atmosphere investing the sea, is precisely the same as that which rests upon the land.

In those countries, also, where earthquakes and volcanos are in full activity, a much shorter period may produce a sensible variation. The climate of the once fertile plain of Malpais in Mexico must differ materially from that which prevailed before the middle of the last century; for, since that time, six mountains,

the highest of them rising sixteen hundred feet above the plateau, have been thrown up by volcanic eruptions. It is by the repetition of an indefinite number of such local revolutions, and by slow movements extending simultaneously over wider areas, as will be afterwards shown, that a general change of climate may finally be brought about.

CHAPTER VIII.

Whether the geographical features of the northern hemisphere, at the period of the deposition of the oldest fossiliferous strata, were such as might have given rise to an extremely hot climate — State of the surface when the mountain limestone and coal were deposited — Changes in physical geography, between the carboniferous period and the chalk — Abrupt transition from the secondary to the tertiary fossils — Accession of land, and elevation of mountain chains, after the consolidation of the secondary rocks — Explanation of Map, showing the area covered by sea, since the commencement of the tertiary period — Astronomical theories of the causes of variations in climate — Theory of the diminution of the supposed primitive heat of the globe.

IN the sixth chapter, I stated the arguments derived from organic remains for concluding that the mean annual temperature of the northern hemisphere was considerably more elevated when the carboniferous and still more ancient strata were deposited than it is at present; also that the climate had been modified more than once since those epochs, and that it had been reduced by successive changes more and more nearly to that now prevailing in the same latitudes. Farther, I endeavoured, in the last chapter, to prove that vicissitudes in climate of no less importance may be expected to recur in future, if it be admitted that causes now active in nature have power, in the lapse of ages, to produce considerable variations in the relative position of land and sea. It remains to inquire whether

the alterations, which the geologist can prove to have *actually taken place* at former periods, in the geographical features of the northern hemisphere, coincide in their nature, and in the time of their occurrence, with such revolutions in climate as would naturally have resulted, according to the meteorological principles already explained.

Period of the primary fossiliferous rocks.—The oldest system of strata which afford by their organic remains any decisive evidence as to climate, or the former position of land and sea, are those generally known as the *transition rocks*, or what I shall term the primary fossiliferous formations.* These have been found in England, France, Germany, Sweden, Russia, and other parts of central and northern Europe, as also in the great Lake district of Canada and the United States. The number and magnitude of the multilocular or chambered univalves, and of the corals, obtained from the limestones of these ancient groups, recall the forms now most largely developed in tropical seas; and some of the species of imbedded testacea and zoophytes are said to be common to very distant latitudes on opposite sides of the equator; as, for example, to Europe and the Falkland Islands, or to North America and the Cape of Good Hope. Should the specific identity of these fossils be confirmed on farther inquiry, their wide geographical range would seem to indicate a far more uniform climate throughout the globe than that now prevailing. Hitherto few, if any, vegetable remains have been noticed; but such as are mentioned are said to agree more nearly with the

* See Elements of Geology, by the Author, ch. 22.

plants of the carboniferous era than any other, and would therefore imply a tropical and humid atmosphere.

This absence or great scarcity of plants as well as of freshwater shells and other indications of neighbouring land, coupled with the wide extent of marine strata of this age in Europe and North America, are facts which imply precisely such a state of physical geography (so far at least as regards the northern hemisphere) as would, according to the principles before explained, give rise to a hot and uniform climate. (See p. 191. and Plate 2. Fig. 1.)

Carboniferous group.— This group comes next in the order of succession ; and one of its principal members, the mountain limestone, was evidently a marine formation, as is shewn by the shells and corals which it contains. That the ocean of that period was of considerable extent in our latitudes, we may infer from the continuity of these calcareous strata over large areas. The same group appears also to have been traced not only through different parts of Europe, but also in North America, towards the borders of the arctic sea.*

* It appears from the observations of Dr. Richardson, made during the expedition under the command of Captain Franklin to the north-west coast of America, and from the specimens presented by him to the Geological Society of London, that, between the parallels of 60° and 70° north latitude, there is a great calcareous formation, stretching towards the mouth of the Mackenzie river, in which are included corallines, productæ, terebratulæ, &c. having a close affinity in generic character to those of our mountain limestone, of which the group has been considered the equivalent. There is also in the same region a newer series of strata, in which

The coal itself is admitted to be of vegetable origin, and the state of the plants, and the beautiful preservation of their leaves in the accompanying shales, precludes the idea of their having been floated from great distances. As the species were evidently terrestrial, we must suppose that some dry land was not far distant; and this opinion is confirmed by the shells and entomostraca found in the upper coal-measures in Shropshire*, where the organic remains indicate a lacustrine deposit. A limestone containing similar fossils at Burdiehouse, near Edinburgh, also implies the former existence of a lake, or rather, perhaps, in this instance, of an estuary, at the remote period under consideration.†

Mr. Hutton states that, in part of the coal-field of Northumberland and Durham, fossil shells of a species of *Unio* are abundant in a shale containing plants of the carboniferous period, and overlying a bed of coal. The coal has been worked out from beneath the shells, which have been already proved to extend over an area five thousand feet square. The shelly stratum is about eighteen inches thick; and the animals have evidently died at various ages, the shells being of every size. Such an accumulation of bivalves of one species, and of a form like the *unio*, seems clearly to indicate the continuance on the spot of a body of

are shales with impressions of ferns, lepidodendrons, and other vegetables, and also ammonites.—*Proceedings of Geol. Soc.* No. 7. p. 68. March, 1828.

* Murchison's Silurian System, p. 84.

† Hibbert, *Trans. R. S. Edin.* vol. xiii.; and L. Horner, *Edin. New Phil. Journ.*, April, 1836.

fresh water, such as might be found in the estuary of a river.*

There are also several regions in Scotland, and in the central and northern parts of England, where the marine mountain-limestone alternates with strata containing coal, in such a manner as to imply the drifting down of plants by rivers into the sea, and the alternate occupation of the same space by fresh and salt water.

The land of the carboniferous period appears to have consisted in part of granitic rocks, the waste of which may have produced such coarse sandstones as the millstone-grit. Volcanic rocks, however, were not wanting, as for example, in Fife and other parts of Scotland where they were poured out on the bottom of the sea, or ejected so as to form tuff during the accumulation of the carboniferous strata.

The arrangement of the sandstones and shales in this group has been thought by some geologists, as by MM. Sternberg, Boué, and Adolphe Brongniart, to favour the hypothesis of the strata having resulted from the waste of small islands placed in rows, and forming the highest points of submarine mountain chains. The disintegration of such clusters of islands might produce around and between them detached deposits, which, when subsequently raised above the waters, would resemble the strata formed in a chain of lakes; for the boundary heights of such apparent lake-basins would be formed of the rocks once constituting the islands, and they might still continue, after their elevation, to preserve their relative superiority of

* Fossil Flora by Lindley and Hutton, part 10.

height, and to surround the newer strata on several sides.*

This idea is also confirmed by the opinion of many botanists who have studied with care the vegetation of the carboniferous period, and who declare that it possesses the character of an insular flora, such as might be looked for in islands scattered through a wide ocean in a tropical and humid climate.

There is, as yet, no well-authenticated instance of the remains of a saurian animal having been found in a member of the carboniferous series.† Now the larger oviparous reptiles usually inhabit rivers of considerable size in warm latitudes; and had crocodiles and other animals of that class been abundant in a fossil state, as in some of the newer secondary formations, we must have inferred the existence of rivers, which could only have drained large tracts of land. Nor have the bones of any terrestrial mammalia rewarded our investigations. Their absence may be regarded by some geologists as corroborating the theory of the non-existence of the higher orders of animals in the earlier ages: but the circumstance may, perhaps, be connected with the geographical condition of the northern hemisphere at that time; for it is a general character of small islands

* See some ingenious speculations to this effect, in the work of M. Ad. Brongniart, *Consid. Générales sur la Nat. de la Végét. &c.*, Ann. des Sci. Nat. Nov. 1828.

† The supposed saurian teeth found by Dr. Hibbert in the carboniferous limestone of Burdiehouse, near Edinburgh, have since been clearly referred by Dr. Agassiz to sauroidal fish; and some remains from Ardwick near Manchester, also said to be saurian, belong most probably to fish.

remote from continents, to be altogether destitute of land quadrupeds, except such as appear to have been conveyed to them by man. Kerguelen's Land, which is of no inconsiderable size, placed in lat. $49^{\circ} 20'$ S., a parallel corresponding to that of the Scilly Islands, may be cited as an example, as may all the groups of fertile islands in the Pacific Ocean between the tropics, where no quadrupeds have been found, except the dog, the hog, and the rat, which have probably been brought to them by the natives; and also bats, which may have made their way along the chain of islands extending from the shores of New Guinea far into the southern Pacific.* But, what is still more remarkable, New Zealand, which may be compared in dimensions to Ireland united with Scotland, which extends over more than 700 miles in latitude, and is in many parts 90 miles broad, with varied stations, a fine climate, and land of all heights, from 14,000 feet downwards, should not possess one indigenous quadruped, with the exception of a small rat.† This fact becomes the more striking, when we recollect that the northern extremity of New Zealand stretches to latitude 34° , where the warmth of the climate must greatly favour the prolific development of organic life.

The various characters then of the carboniferous strata which have been enumerated — the continuity of the marine mountain-limestone over vast spaces — the apparent derivation of the fragmentary rocks from the waste of islands — the submarine aspect of the volcanic products — the insular character of the flora

* Prichard's Phys. Hist. of Mankind, vol. i. p. 75.

† Darwin's Journal, p. 511.

— the absence of large fluviatile reptiles and of land quadrupeds — all concur to establish the fact of the northern hemisphere having been pervaded by a great ocean, interspersed, like the south Pacific, with small islets or lands of moderate dimensions, and with insular or submarine volcanos. It has already been shewn that such a combination of geographical circumstances, if not neutralized by others of a contrary tendency in the southern hemisphere, must give rise to a general warmth and uniformity of climate throughout the globe.

Changes in physical geography between the formation of the carboniferous strata and the chalk.—We have evidence in England that the strata of the ancient carboniferous group, already adverted to, were, in many instances, fractured and contorted, and often thrown into a vertical position before the deposition of some of the newer secondary rocks, such as the new red sandstone.

Fragments of the older formations are sometimes included in the conglomerates of the more modern ; and some of these fragments still retain their fossil shells and corals, so as to enable us to determine the parent rocks from whence they were derived. There are other proofs of the disturbance at successive epochs of different secondary rocks before the deposition of others ; and satisfactory evidence that, during these reiterated convulsions, the geographical features of the northern hemisphere were frequently modified, and that from time to time new lands emerged from the deep. The vegetation, during some parts of the period in question (from the lias to the chalk inclu-

sive), appears to have approached to that of the larger islands of the equatorial zone ; such, for example, as we now find in the West Indian archipelago.* These islands appear to have been drained by rivers of considerable size, which were inhabited by crocodiles and gigantic oviparous reptiles, both herbivorous and carnivorous, belonging for the most part to extinct genera. Of the contemporary inhabitants of the land we have as yet acquired but scanty information, but we know that there were flying reptiles, insects, and small mammifers, allied to the marsupial tribes.

A freshwater deposit, called the Wealden, occurs in the upper part of the secondary series of the south of England, which, by its extent and fossils, attests the existence in that region of a large river draining a continent or island of considerable dimensions. We know that this land was clothed with wood, and inhabited by huge terrestrial reptiles and birds. Its position so far to the north as the counties of Surrey and Sussex, at a time when the mean temperature of the climate is supposed to have been much hotter than at present, may at first sight appear inconsistent with the theory before explained, that the heat was caused by the gathering together of all the great masses of land in low latitudes, while the northern regions were almost entirely sea. But it must not be taken for granted that the geographical conditions already described (p. 191., and Plate 2. Fig. 1.) as capable of producing the extreme of heat were ever combined at any geological period of which we have as

* Ad. Brongniart, *Consid. Générales sur la Nat. de la Végét. &c.*, Ann. des Sci. Nat., Nov. 1828.

yet obtained information. It is more probable, from what has been stated in the preceding chapters, that a slight approximation to such an extreme state of things would be sufficient; in other words, if most of the dry land were tropical, and scarcely any of it arctic or antarctic, a prodigious elevation of temperature must ensue, even though a part of some continents should penetrate far into the temperate zones.

Changes during the tertiary periods. — The secondary and tertiary formations of Europe, when considered separately, may be contrasted as having very different characters; the secondary appearing to have been deposited in open seas, the tertiary in regions where dry land, lakes, bays, and perhaps inland seas, abounded. The secondary series is almost exclusively marine; the tertiary, even the oldest part, contains lacustrine strata, and not unfrequently freshwater and marine beds alternating. In fact, there is evidence of important geographical changes having occurred between the deposition of the cretaceous system, or uppermost of the secondary series, and that of the oldest tertiary formations. This change in the physical geography of Europe was accompanied by an alteration no less remarkable in organic life, scarcely any *species* being common both to the secondary and tertiary rocks, and the fossils of the latter affording evidence of a different climate.

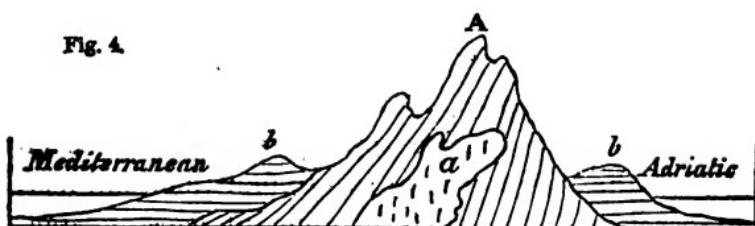
On the other hand, when we compare the tertiary formations of successive ages, we trace a gradual approximation in the imbedded fossils, from an assemblage in which extinct species predominate to one where the species agree for the most part with those now existing. In other words, we find a

gradual increase of animals and plants fitted for our present climates, in proportion as the strata which we examine are more modern. Now, during all these successive tertiary periods, there are signs of a great increase of land in European latitudes. By reference to the map (Pl. 3.), and its description, p. 211., the reader will see that about two thirds of the present European lands have emerged since the earliest tertiary group originated. Nor is this the only revolution which the same region has undergone within the period alluded to, some tracts which were previously land having gained in altitude, others, on the contrary, having sunk below their former level.

That the existing lands were not all upheaved at once into their present position is proved by the most striking evidence. Several Italian geologists, even before the time of Brocchi, had justly inferred that the Apennines were elevated several thousand feet above the level of the Mediterranean, before the deposition of the modern Subapennine beds which flank them on either side. What now constitutes the central calcareous chain of the Apennines must for a long time have been a narrow ridgy peninsula, branching off, at its northern extremity, from the Alps near Savona. This peninsula has since been raised from one to two thousand feet, by which movement the ancient shores, and, for a certain extent, the bed of the contiguous sea, have been laid dry, both on the side of the Mediterranean and the Adriatic.

The nature of these vicissitudes will be explained by the accompanying diagram, which represents a transverse section across the Italian peninsula. The inclined strata A are the disturbed formations of the

Fig. 4.



Apennines into which the ancient igneous rocks *a* are supposed to have intruded themselves. At a lower level on each flank of the chain are the more recent shelly beds *b b*, which often contain rounded pebbles derived from the waste of contiguous parts of the older Apennine limestone. These, it will be seen, are horizontal, and lie in what is termed "unconformable stratification" on the more ancient series. They now constitute a line of hills of moderate elevation between the sea and the Apennines, but never penetrate to the higher and more ancient valleys of that chain.

The same phenomena are exhibited in the Alps on a much grander scale; those mountains being composed in some even of their higher regions of newer secondary formations, while they are encircled by a great zone of tertiary rocks of different ages, both on their southern flank towards the plains of the Po, and on the side of Switzerland and Austria, and at their eastern termination towards Styria and Hungary.* This tertiary zone marks the position of former seas or gulfs, like the Adriatic, which were many thousand

* See a Memoir on the Alps, by Professor Sedgwick and Mr. Murchison, Trans. of Geol. Soc. second ser. vol. iii., accompanied by a map.

feet deep, and wherein masses of strata accumulated, some single groups of which seem scarcely inferior in thickness to the whole of our secondary formations in England. These marine tertiary strata have been raised to the height of from two to four thousand feet, and consist of formations of different ages, characterized by different assemblages of organized fossils. The older tertiary groups generally rise to the greatest heights, and form interior zones nearest to the central ridges of the Alps. Although we have not yet ascertained the number of different periods at which the Alps gained accessions to their height and width, yet we can affirm, that the last series of movements occurred when the seas were inhabited by many existing species of animals.

We may imagine some future series of convulsions once more to heave up this stupendous chain, together with the adjoining bed of the sea, so that the mountains of Europe may rival the Andes in elevation; in which case the deltas of the Po, Adige, and Brenta, now encroaching upon the Adriatic, might be uplifted so as to form another exterior belt of considerable height around the south-eastern flank of the Alps.

The Pyrenees, also, have acquired the whole of their present altitude, which in Mont Perdu exceeds eleven thousand feet, since the deposition of some of the newer or cretaceous members of our secondary series. The granitic axis of that chain only attains about the same height as a ridge formed by marine calcareous beds, the organic remains of which show them to be the equivalents of our chalk and green-sand se-

ries.* The tertiary strata at the base of the chain are raised to the height of only a few hundred feet above the sea, and retain a horizontal position, without partaking in general in the disturbances to which the older series has been subjected; so that the great barrier between France and Spain was almost entirely upheaved in the interval between the deposition of the chalk and certain tertiary strata. The Jura, also, owes a great part of its present elevation to subterranean convulsions which happened after the deposition of certain tertiary groups.†

The remarkable break above alluded to, between the most modern of the known secondary rocks and the oldest tertiary, may be in some measure apparent only, and ascribable to the present deficiency of our information; in which case the signs of the intermediate steps, by which a passage was effected from one state of things to another, may hereafter be discovered. Nevertheless, it is far from impossible that the interval between the chalk and tertiary formations constituted an era in the earth's history, when the transition from one class of organic beings to another was, comparatively speaking, rapid. For if the doctrines above explained in regard to vicissitudes of temperature are sound, it will follow that changes of equal magnitude in the geographical features of the globe may at different periods produce very unequal effects on climate; and, so far as the existence of certain animals and plants depends on climate, the duration of species

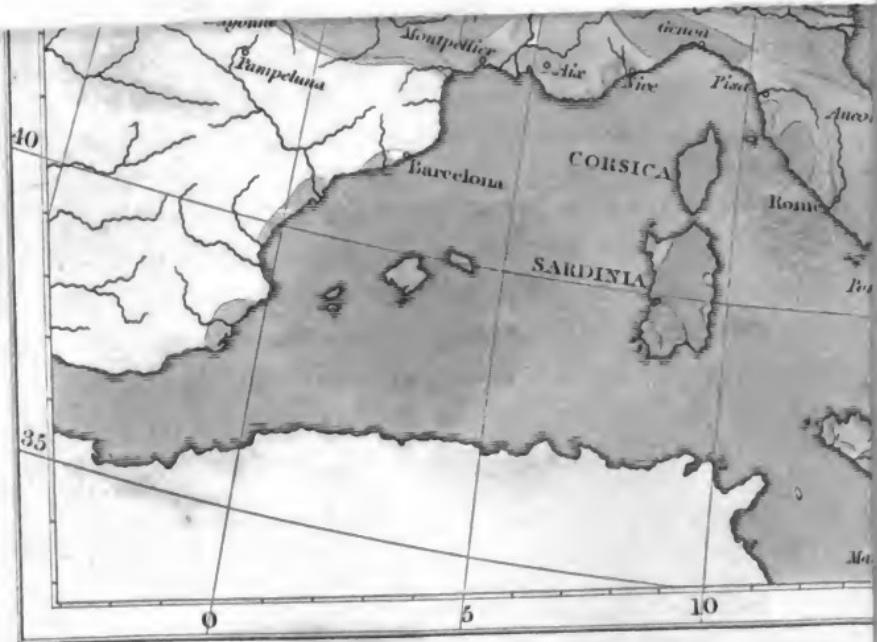
* This observation, first made by M. Boué, has been since confirmed by M. Dufrénoy.

† M. Elie de Beaumont, Ann. des Sci. Nat., Dec. 1829, p. 346.

would be shortened or protracted, according to the rate at which the change of temperature proceeded.

For even if we assume that the intensity of the subterranean disturbing forces is uniform and capable of producing nearly equal amounts of alteration on the surface of the planet, during equal periods of time, still the rate of alteration in climate would be by no means uniform. Let us imagine the quantity of land between the equator and the tropic in one hemisphere to be to that in the other as thirteen to one, which, as before stated, represents the unequal proportion of the extra-tropical lands in the two hemispheres at present. Then let the first geographical change consist in the shifting of this preponderance of land from one side of the line to the other; from the southern hemisphere, for example, to the northern. Now this need not affect the *general* temperature of the earth. But if, at another epoch, we suppose a continuance of the same agency to transfer an equal volume of land from the torrid zone to the temperate and arctic regions of the northern and southern hemisphere, or into one of them, there might be so great a refrigeration of the mean temperature *in all latitudes*, that scarcely any of the pre-existing races of animals would survive; and, unless it pleased the Author of Nature that the planet should be uninhabited, new species would then be substituted in the room of the extinct. We ought not, therefore, to infer that equal periods of time are always attended by an equal amount of change in organic life, since a great fluctuation in the mean temperature of the earth, the most influential cause which can be conceived in exterminating whole races of animals and plants, must, in different epochs, require unequal portions of time for its completion.

would be shortened or protracted, according to the rate



*Map showing the extent of surface in Europe which has been covered by water since the commencement of the deposition of the older or Eocene Tertiary strata. (Strata of the Paris and London Basins, &c.)**

THIS map will enable the reader to perceive at a glance the great extent of change in the physical geography of Europe, which can be proved to have taken place since some of the older tertiary strata began to be deposited. The proofs of submergence, during some part or other of this period, in all the districts distinguished by ruled lines, are of a most unequivocal character; for the area thus described is now covered by deposits containing the fossil remains of animals which could only have lived under water. The most ancient part of the period referred to cannot be deemed very remote, considered geologically; because the deposits of the Paris and London basins, of Auvergne, and many other districts belonging to the older tertiary epoch, are newer than the greater part of the sedimentary rocks (those commonly called secondary and transition) of which the crust of the globe is composed. The species, moreover, of marine and freshwater testacea, of which the remains are found in these older tertiary formations, are not entirely distinct from such as now live. Yet, notwithstanding the comparatively recent epoch to which this retrospect is carried, the variations in the distribution of land and sea depicted on the map form only a part of those which must have taken place during the period under

* Constructed chiefly from M. Ami Boué's Geological Map of Europe.

consideration. Some approximation has merely been made to an estimate of the amount of *sea converted into land* in parts of Europe best known to geologists; but we cannot determine how much land has become sea during the same period; and there may have been repeated interchanges of land and water in the same places, changes of which no account is taken in the map, and respecting the amount of which little accurate information can ever be obtained.

I have extended the sea in two or three instances beyond the limits of the land now covered by tertiary formations, because other geological data have been obtained for inferring the submergence of these tracts after the deposition of the tertiary strata had begun. Thus, for example, there are good reasons for concluding that part of the chalk of England (the North and South Downs, for example, together with the intervening secondary tracts) continued beneath the sea until the Eocene or earliest tertiary beds had begun to accumulate.

A strait of the sea separating England and Wales has also been introduced, on the evidence afforded by shells of existing species found in a deposit of gravel, sand, loam, and clay, called the northern drift by Mr. Murchison, who has traced it from Lancashire to the Bristol channel, over the space indicated in the map.* Mr. Trimmer has discovered similar recent marine shells on the northern coast of North Wales, and on Moel Tryfane, near the Menai Straits, at the height of 1392 feet above the level of the sea!

Some raised sea-beaches, one of them at the mouth

* See Proceedings of Geol. Soc. vol. ii. p. 934.

of Carlingford Bay, Ireland, in which recent marine shells occur, lately observed by Professor Sedgwick and Mr. Murchison, have required an extension of the sea over part of the eastern shore of Ireland.

A portion also of the primary district in Brittany is divided into islands, because it has been long known to be covered with patches of marine tertiary strata; and when I examined the disposition of these, in company with my friend Captain S. E. Cook, R. N., in 1830, I was convinced that the sea must have covered much larger areas than are now occupied by these small and detached deposits.

The former connexion of the White Sea and the Gulf of Finland is proved by the fact that a broad band of tertiary strata extends throughout part of the intervening space. The channel, it is true, is represented as somewhat broader than the tract now occupied by the tertiary formation; because the latter is bordered on the north-west by a part of Finland, which is extremely low, and so thickly interspersed with lakes as to be nearly half covered with fresh water.

Certain portions of the western shores of Norway and Sweden have been left blank, because the discovery by Von Buch, Brongniart, and others of deposits of recent shells along the coasts of those countries, at several places and at various heights above the level of the sea, attests the comparatively recent date of the elevation of part of the gneiss and other primary rocks in that country, although we are unable as yet to determine how far the sea may have extended.

On the other hand, a considerable space of low land along the shores on both sides of the Gulf of Bothnia, in the Baltic, is represented as sea, because the gra-

dual rise of the land and the shoaling of the water on that coast, known to have taken place during the historical era, leave no room for doubt that the boundaries of the gulf must have been greatly contracted within a comparatively modern period. Beds of sand and clay are also found far inland in these parts, containing fossil shells of species now inhabiting the neighbouring seas. A portion of Scania, and other tracts in the south of Sweden, have also been marked with ruled lines, because they are covered with clay, sand, and erratic blocks, which appeared to me, after examining the district, to be tertiary. If the space overspread by such formations were more accurately known, the area represented as land in this as well as in England and many other parts of Europe would, doubtless, be far more circumscribed.

I was anxious, even in the title of this map, to guard the reader against the supposition that it was intended to represent the state of the physical geography of part of Europe at any *one point of time*. The difficulty, or rather the impossibility, of restoring the geography of the globe as it may have existed at any former period, especially a remote one, consists in this, that we can only point out where part of the sea has been turned into land, and are almost always unable to determine what land may have become sea. All maps, therefore, pretending to represent the geography of remote geological epochs must be ideal. The map under consideration is not a restoration of a former state of things, at any particular moment of time, but a synoptical view of a certain amount of one kind of change (the conversion of sea into land) known to have been brought about within a given period.

It may be stated that the movements of earth-

quakes occasion the subsidence as well as the upraising of the surface ; and that, by the alternate rising and sinking of particular spaces at successive periods, a great area may have been entirely covered with marine deposits, although the whole may never have been beneath the waters at one time ; nay, even though the relative proportion of land and sea may have continued unaltered throughout the whole period. I believe, however, that since the commencement of the tertiary period, the dry land in the northern hemisphere has been continually on the increase, both because it is now greatly in excess beyond the average proportion which land generally bears to water on the globe, and because a comparison of the secondary and tertiary strata affords indications, as I have already shown, of a passage from the condition of an ocean interspersed with islands to that of a large continent.*

But supposing it were possible to represent all the vicissitudes in the distribution of land and sea that have occurred during the tertiary period, and to exhibit not only the actual existence of land where there was once sea, but also the extent of surface now submerged which may once have been land, the map would still fail to express all the important revolutions in physical geography which have taken place within the epoch under consideration. For the oscillations of level, as was before stated, have not merely been such as to lift up the land from below the waters, but in some cases to occasion a rise of several thousand feet above the sea. Thus the Alps have acquired an additional altitude of from 2000 to 4000 feet, and even in some places still more ; and the Apennines owe a considerable part of their height (from 1000 to 2000

* See p. 204.

feet and upwards) to subterranean convulsions which have happened within the tertiary epoch.

On the other hand, some mountain chains may have been lowered during the same series of ages, in an equal degree, and shoals may have been converted into deep abysses.*

Concluding remarks on changes in physical geography.
—The foregoing observations, it may be said, are confined to Europe, and therefore merely establish the increase of dry land in a space which constitutes but a small portion of the northern hemisphere; but it was stated in the preceding chapter, that the great Lowland of Siberia, lying chiefly between the latitudes 55° and 75° N. (an area nearly equal to all Europe), is covered for the most part by marine strata, which, from the account given by Pallas, and other writers, may be considered as belonging to the tertiary period. The emergence, therefore, of this area from the deep is, comparatively speaking, a modern event, and must, as before remarked, have caused a great increase of cold throughout the globe.

Upon a review, then, of all the facts above enumerated, there appear grounds for inferring that the eras of the principal alterations in climate, as deduced from fossil remains, were coincident with the periods of the most remarkable changes in the former position of sea and land. A wide expanse of ocean, interspersed with islands, seems to have pervaded the northern hemi-

* It may be observed, that the facts and inferences exhibited in this map bear not merely on the theory of climate above proposed, but serve also to illustrate the views explained in the third Book respecting the migrations of animals and plants, and the gradual extinction of species.

sphere at the periods when the transition and carboniferous rocks were formed, and the temperature was then hottest and most uniform. Subsequent modifications in climate accompanied the deposition of the secondary formations, when repeated changes were effected in the physical geography of our northern latitudes. Lastly, the refrigeration became most decided, and the climate most nearly assimilated to that now enjoyed, when the lands in Europe and northern Asia had attained their full extension, and the mountain chains their actual height.

It has been objected to this theory of climate, that there are no geological proofs of the prevalence at any former period of a temperature *lower* than that now enjoyed; whereas, if the causes above assigned were the true ones, it might reasonably have been expected that fossil remains would sometimes indicate colder as well as hotter climates than those now established.* In answer to this objection, I may suggest, that our present climates are probably far more distant from the extreme of possible heat than from its opposite extreme of cold. A glance at the map (Pl. 2. fig. 1.) will show that all the existing lands might be placed between the 30th parallels of latitude on each side of the equator, and that even then they would by no means fill that space. In no other position would they give rise to so high a temperature. But the present geographical condition of the earth is so far removed from such a state of things, that the land lying between the poles and the parallels of 30, is in great excess; so much so that, instead of being to the sea in the proportion of 1 to 3, which is as near as possible the

* Allgemeine Literatur Zeitung, No. cxxxix. July, 1899.

average general ratio throughout the globe, it is as 9 to 23.* Hence it ought not to surprise us if, in our geological retrospect, embracing, perhaps, a small part only of a complete cycle of change in the terrestrial climates, we should happen to discover every where the signs of a higher temperature. The strata hitherto examined may have originated when the quantity of equatorial land was always decreasing, and the land in regions nearer the poles augmenting in height and area, until at length it attained its present excess in high latitudes. There is nothing improbable in supposing that the geographical revolutions of which we have hitherto obtained proofs had this general tendency; and in that case the refrigeration must have been constant, although, for reasons before explained, the rate of cooling may not have been uniform.

It may, however, be as well to observe here, that indications have lately been remarked of oscillations of temperature in the period immediately preceding the human era. On examining some of the most modern deposits, both in Scotland, Ireland, and Canada, in which nearly all, in some cases, perhaps all, the fossil shells are of recent species, we discover the signs of a

* In this estimate, the space within the antarctic circle, of which nothing certain is known, is not taken into account: if included, it would probably add to the excess of dry land: for the great accumulation of ice in the antarctic region seems to imply the presence of a certain quantity of terra firma. The number of square miles on the surface of the globe, are 148,522,000, the part occupied by the sea being 110,849,000, and that by land, 37,673,000; so that the land is very nearly to the sea as 1 part in 4. I am informed by Mr. Gardner, that, according to a rough approximation, the land between the 30° N. lat. and the pole occupies a space about equal to that of the sea, and the land between the 30° S. lat. and the antarctic circle about $\frac{1}{4}$ of that zone.

colder climate than that now prevailing in corresponding latitudes on both sides the Atlantic. This opinion is derived partly from the known habitations of the corresponding living species, and partly from the abundance of certain genera of shells and the absence of others.* The date of the refrigeration thus inferred appears to coincide with the era of the dispersion of erratic blocks over Europe and North America, a phenomenon which will be ascribed in the sequel (Book II. chap. iii.), to the cold then prevailing in the northern hemisphere.

Astronomical causes of fluctuations in climate.—Sir John Herschel has lately inquired, whether there are any astronomical causes which may offer a possible explanation of the difference between the actual climates of the earth's surface, and those which formerly appear to have prevailed. He has entered upon this subject, he says, “impressed with the magnificence of that view of geological revolutions, which regards them rather as regular and necessary effects of great and general causes, than as resulting from a series of convulsions and catastrophes, regulated by no laws, and reducible to no fixed principles.” Geometers, he adds, have demonstrated the absolute invariability of the mean distance of the earth from the sun; whence it would at first seem to follow, that the mean annual supply of light and heat derived from that luminary would be alike invariable: but a closer consideration of the subject will show, that this would not be a legitimate conclusion; but that, on the contrary, the *mean* amount of solar radiation is dependent on the excen-

* See papers by Mr. Smith of Jordanhill, F.G.S., and the author, *Proceedings Geol. Soc.*, No. 63., 1839.

tricity of the earth's orbit, and therefore liable to variation.*

Now, the excentricity of the orbit, he continues, is actually diminishing, and has been so for ages beyond the records of history. In consequence, the ellipse is in a state of approach to a circle, and the annual average of solar heat radiated to the earth is actually on the *decrease*. So far this is in accordance with geological evidence, which indicates a general refrigeration of climate ; but the question remains, whether the amount of diminution which the excentricity may have ever undergone, can be supposed sufficient to account for any sensible refrigeration. The calculations necessary to determine this point, though practicable, have never yet been made, and would be extremely laborious ; for they must embrace all the perturbations which the most influential planets, Venus, Mars, Jupiter, and Saturn, would cause in the earth's orbit, and in each other's movements round the sun.

The problem is also very complicated, inasmuch as it depends not merely on the ellipticity of the earth's orbit, but on the assumed temperature of the celestial spaces beyond the earth's atmosphere ; a matter still open to discussion, and on which MM. Fourier and Herschel have arrived at very different opinions. But if, says Herschel, we suppose an extreme case, as if the earth's orbit should ever become as excentric as

* The theorem is thus stated : — “ The excentricity of the orbit varying, the total quantity of heat received by the earth from the sun in one revolution is inversely proportional to the minor axis of the orbit. The major axis is invariable, and therefore, of course, the absolute length of the year ; hence it follows that the mean annual average of heat will also be in the same inverse ratio of the minor axis.” — Geol. Trans. second series, vol. iii. p. 295.

that of the planet Juno, or Pallas, a great change of climate might be conceived to result, the winter and summer temperatures being sometimes mitigated, and at others exaggerated, in the same latitudes.

It is much to be desired that the calculations alluded to were executed, as even if they should demonstrate, as M. Arago thinks highly probable *, that the mean amount of solar radiation can never be materially affected by irregularities in the earth's motion, it would still be satisfactory to ascertain the point. Such inquiries, however, can never supersede the necessity of investigating the consequences of the varying position of continents, shifted as we know them to have been during successive epochs, from one part of the globe to the other.

Another astronomical hypothesis respecting the possible cause of secular variations in climate, has been proposed by a distinguished mathematician and philosopher, M. Poisson. He begins by assuming, 1st, that the sun and our planetary system are not stationary, but carried onward by a common movement through space ; 2dly, that every point in space receives heat as well as light from innumerable stars surrounding it on all sides, so that if a right line of indefinite length be produced in any direction from such point, it must encounter a star either visible or invisible to us. 3dly, He then goes on to assume, that the different regions of space, which in the course of millions of years are traversed by our system, must be of very unequal temperature, inasmuch as some of them must receive a greater, others a less quantity of radiant heat from the great stellar inclosure. If the earth,

* Ann. du Bur. des Long. 1834.

he continues, or any other large body, pass from a hotter to a colder region, it would not readily lose in the second all the heat which it has imbibed in the first region, but retain a temperature increasing downwards from the surface, as in the actual condition of our planet.*

Now the opinion originally suggested by Sir W. Herschel, that our sun and its attendant planets were all moving onward through space, in the direction of the constellation Hercules, is still thought by many eminent astronomers to require confirmation. If its reality be matter of doubt, still more vague and uncertain are all conjectures as to its amount; and great indeed must be the extent of the movement before this cause alone can work any material alteration in the terrestrial climates. M. Poisson has supposed, for the sake of illustration, that the temperature of the space through which our system has passed before arriving at the place which it now occupies in the heavens, exceeded 212° Fahr., in which case he can explain the observed rate at which the heat increases as we descend downwards from the surface of the earth. But the temperature of boiling water, or 212° Fahr., is now very rarely developed in dry sand exposed to the rays of the noonday sun at the equator; the idea, therefore, of the surface of the entire globe having, at any period, received from the stars alone (in the night for example) a glare of light and heat beyond that now generated by a tropical sun, is enough to alarm the most fearless imagination.

Variable splendour of stars.— There is still another astronomical suggestion respecting the possible causes of secular variations in the terrestrial climates

* Poisson, Théorie Mathémat. de la Chaleur, Comptes Rendus de l'Acad. des Sci., Jan. 30. 1837.

which deserves notice. It has long been known that certain stars are liable to great and periodical fluctuations in splendour, and Sir J. Herschel has lately ascertained (Jan. 1840), that a large and brilliant star, called *alpha* Orionis, sustained, in the course of six weeks, a loss of nearly half its light. "This phenomenon," he remarks, "cannot fail to awaken attention, and revive those speculations which were first put forth by my father, Sir W. Herschel, respecting the possibility of a change in the lustre of our sun itself. If there really be a community of nature between the sun and fixed stars, every proof that we obtain of the extensive prevalence of such periodical changes in those remote bodies, adds to the probability of finding something of the kind nearer home." Referring then to the possible bearing of such facts on ancient revolutions in terrestrial climates, he says, that "it is a matter of observed fact, that many stars *have* undergone, in past ages, within the records of astronomical history, very extensive changes in apparent lustre, without a change of distance adequate to producing such an effect. If our sun were even *intrinsically* much brighter than at present, the mean temperature of the surface of our globe would, of course, be proportionally greater. I speak now not of periodical, but of secular changes. But the argument is complicated with the consideration of the possibly imperfect transparency of the celestial spaces, and with the cause of that imperfect transparency, which may be due to material non-luminous particles diffused irregularly in patches analogous to nebulæ, but of greater extent — to *cosmical clouds*, in short — of whose existence we have, I think, some indication in the singular and apparently capricious phenomena

of temporary stars, and perhaps in the recent extraordinary sudden increase and hardly less sudden diminution of η *Argus*." *

Supposed gradual diminution of the earth's primitive heat. — The gradual diminution of the supposed primitive heat of the globe has been resorted to by many geologists as the principal cause of alterations of climate. The matter of our planet is imagined, in accordance with the conjectures of Leibnitz, to have been originally in an intensely heated state, and to have been parting ever since with portions of its heat, and at the same time contracting its dimensions. There are, undoubtedly, good grounds for inferring, from recent observation and experiment, that the temperature of the earth increases as we descend from the surface to that slight depth to which man can penetrate ; but there are no positive proofs of a secular decrease of internal heat accompanied by contraction. On the contrary, La Place has shown, by reference to astronomical observations made in the time of Hipparchus, that in the last two thousand years at least there has been no sensible contraction of the globe by cooling ; for had this been the case, even to an extremely small amount, the day would have been shortened, whereas its length has certainly not diminished during that period by $\frac{1}{300}$ th of a second.

Baron Fourier, after making a curious series of experiments on the cooling of incandescent bodies, considers it to be proved mathematically, that the actual distribution of heat in the earth's envelope is precisely that which would have taken place if the globe had been formed in a medium of a very high tem-

* *Proceedings Roy. Astronom. Soc.* No. iii. Jan. 1840.

perature, and had afterwards been constantly cooled.* He contends, that although no contraction can be demonstrated to have taken place within the historical period (the operation being slow and the time of observation limited), yet it is no less certain that heat is annually passing out by radiation from the interior of the globe into the planetary spaces. He even undertook to demonstrate that the quantity of heat thus transmitted into space in the course of every century, through every square metre of the earth's surface, would suffice to melt a column of ice having a square metre for its base, and being three metres (or 9 feet 10 inches) high.

It is at the same time denied, that there is any assignable mode in which the heat thus lost by radiation can be again restored to the earth, and consequently the interior of our planet must, from the moment of its creation, have been subject to refrigeration, and is destined for ever to grow colder. But I shall point out, in the 19th Chapter of the second Book, many objections to the theory of the intense heat of the earth's central nucleus, and shall then inquire how far the observed augmentation of temperature as we descend below the surface, may be referable to other causes unconnected with the supposed pristine fluidity of the entire globe.

* See a Memoir on the Temperature of the Terrestrial Globe, and the Planetary Spaces, *Ann. de Chimie et Phys.* tom. xxvii. p. 136. Oct. 1824.

CHAPTER IX.

THEORY OF THE PROGRESSIVE DEVELOPMENT OF ORGANIC LIFE AT SUCCESSIVE GEOLOGICAL PERIODS.

Theory of the progressive development of organic life — Evidence in its support inconclusive — Vertebrated animals, and plants of the most perfect organization, in strata of very high antiquity — Differences between the organic remains of successive formations — Comparative modern origin of the human race — The popular doctrine of successive development not established by the admission that man is of modern origin — Introduction of man, to what extent a change in the system.

Successive development of organic life. — IN the preceding chapters I have considered whether revolutions in the general climate of the globe afford any just ground of opposition to the doctrine that the former changes of the earth which are treated of in geology belong to one uninterrupted series of physical events governed by ordinary causes. Against this doctrine some popular arguments have been derived from the great vicissitudes of the organic creation in times past; I shall therefore proceed to the discussion of such objections, especially as they have been formally advanced in these words by a late distinguished philosopher, Sir H. Davy. “It is impossible,” he affirms, “to defend the proposition, that the present order of things is the ancient and constant order of nature, only modified by existing laws: in those strata which are deep-

est, and which must, consequently, be supposed to be the earliest deposited, forms even of vegetable life are rare ; shells and vegetable remains are found in the next order ; the bones of fishes and oviparous reptiles exist in the following class ; the remains of birds, with those of the same genera mentioned before, in the next order ; those of quadrupeds of extinct species in a still more recent class ; and it is only in the loose and slightly consolidated strata of gravel and sand, and which are usually called diluvian formations, that the remains of animals such as now people the globe are found, with others belonging to extinct species. But, in none of these formations, whether called secondary, tertiary, or diluvial, have the remains of man, or any of his works, been discovered ; and whoever dwells upon this subject must be convinced, that the present order of things, and the comparatively recent existence of man as the master of the globe, is as certain as the destruction of a former and a different order, and the extinction of a number of living forms which have no types in being. In the oldest secondary strata there are no remains of such animals as now belong to the surface ; and in the rocks, which may be regarded as more recently deposited, these remains occur but rarely, and with abundance of extinct species ;—there seems, as it were, a gradual approach to the present system of things, and a succession of destructions and creations preparatory to the existence of man." *

In the above passages, the author deduces two important conclusions from geological data : first, that in the successive groups of strata, from the oldest to the

* Sir H. Davy, *Consolations in Travel, Dialogue III. "The Unknown."*

most recent, there is a progressive development of organic life, from the simplest to the most complicated forms; — secondly, that man is of comparatively recent origin, and these conclusions he regards as inconsistent with the doctrine, “that the present order of things is the ancient and constant order of nature only modified by existing laws.”

With respect, then, to the first of these propositions, we may ask whether the theory of the progressive development of animal and vegetable life, and their successive advancement from a simple to a more perfect state, has any secure foundation in fact? No geologists who are in possession of all the data now established respecting fossil remains, will for a moment contend for the doctrine in all its detail, as laid down by the great chemist to whose opinions we have referred; but naturalists, who are not unacquainted with recent discoveries, continue to defend it in a modified form. They say that, in the first period of the world, (by which they mean the earliest of which we have yet procured any memorials,) the vegetation consisted almost entirely of cryptogamic plants, while the animals which co-existed were almost entirely confined to zoophytes, testacea, and a few fish. Plants of a less simple structure succeeded in the next epoch, when oviparous reptiles began also to abound. Lastly, the terrestrial flora became most diversified and most perfect when the highest orders of animals, the mammalia and birds, were called into existence.

Now in the first place, it may be observed, that many naturalists are guilty of no small inconsistency in endeavouring to connect the phenomena of the earliest vegetation with a nascent condition of organic life, and at the same time to deduce from the numerical

predominance of certain types of form, the greater heat of the ancient climate. The arguments in favour of the latter conclusion are without any force, unless we can assume that the rules followed by the Author of Nature in the creation and distribution of organic beings were the same formerly as now; and that, as certain families of animals and plants are now most abundant in, or exclusively confined to, regions where there is a certain temperature, a certain degree of humidity, a certain intensity of light, and other conditions, so also the same phenomena were exhibited at every former era.

If this postulate be denied, and the prevalence of particular families be declared to depend on a certain order of precedence in the introduction of different classes into the earth, and if it be maintained that the standard of organization was raised successively, we must then ascribe the numerical preponderance, in the earlier ages, of plants of simpler structure, *not to the heat*, but to those different laws which regulate organic life in newly created worlds. If, according to the laws of progressive development, cryptogamic plants always flourish for ages before the dicotyledonous order can be established, then is the small proportion of the latter fully explained; for in this case, whatever may have been the mildness or severity of the climate, they could not make their appearance.

Before we can infer an elevated temperature in high latitudes, from the presence of arborescent Ferns, Lycopodiaceæ, and plants of other allied families, we must be permitted to assume, that at all times, past, present, and future, a heated and moist atmosphere pervading the northern hemisphere has a tendency to

produce in the vegetation a predominance of analogous types of form.

In the ancient strata of the carboniferous era, between 200 and 300 species of plants have been found. In these, says the authors of the "Fossil Flora *," no traces have been as yet discovered of the simplest forms of flowerless vegetation, such as Fungi, Lichens, Hepaticæ, or Mosses; while, on the contrary, there appear in their room Ferns, Lycopodiaceæ, and supposed Equisetaceæ, the most perfectly organized cryptogamic plants. In regard to the remains of monocotyledons of the same strata, they consist of palms and plants analogous to Dracænas, Bananas, and the Arrow Root tribe, which are the most highly developed tribes of that class. Among the dicotyledons of the same period coniferous trees were abundant, while the fossil Stigmariæ, which accompany them, belonged probably to the most perfectly organized plants of that class, being allied to the Cacteæ, or Euphorbiaceæ. "But supposing," continue the same authors, "that it could be demonstrated, that neither Coniferæ nor any other dicotyledonous plants existed in the first geological age of land plants, still the theory of progressive development would be untenable; because it would be necessary to show that monocotyledons are inferior in dignity, or, to use a more intelligible expression, are less perfectly formed than dicotyledons. So far is this from being the case, that if the exact equality of the two classes were not admitted, it would be a question whether monocotyledons are not the more highly organized of the two; whether palms are

* Fossil Flora of Great Britain, by John Lindley and William Hutton, Esquires. London, 1832. Preface.

not of greater dignity than oaks, and cerealia than nettles."

By far the largest part of the organic remains found in the earth's crust consist of corals and testacea, the bones of vertebrated animals being comparatively rare. When these occur, they belong much more frequently to fish than to reptiles, and but seldom to terrestrial mammalia. This might, perhaps, have been anticipated as the general result of investigation, since all are now agreed that the greater number of fossiliferous strata were deposited beneath the sea, and that the ocean probably occupied in ancient times, as now, the greater part of the earth's surface. We must not, however, too hastily infer from the absence of fossil bones of mammalia in the older rocks, that the highest class of vertebrated animals did not exist in remoter ages. There are regions at present, in the Indian and Pacific oceans, co-extensive in area with the continents of Europe and North America, where we might dredge the bottom and draw up thousands of shells and corals, without obtaining one bone of a land quadruped. Suppose our mariners were to report, that on sounding in the Indian Ocean near some coral reefs, and at some distance from the land, they drew up on hooks attached to their line portions of a leopard, elephant, or tapir, should we not be sceptical as to the accuracy of their statements? and if we had no doubt of their veracity, might we not suspect them to be unskilful naturalists? or, if the fact were unquestioned, should we not be disposed to believe that some vessel had been wrecked on the spot?

The casualties must always be rare by which land quadrupeds are swept by rivers far out into the open sea, and still rarer the contingency of such a floating

body not being devoured by sharks or other predaceous fish, such as were those of which we find the teeth preserved in some of the carboniferous strata. But if the carcass should escape, and should happen to sink where sediment was in the act of accumulating, and if the numerous causes of subsequent disintegration should not efface all traces of the body, included for countless ages in solid rock, is it not contrary to all calculation of chances that we should hit upon the exact spot — that mere point in the bed of an ancient ocean, where the precious relic was entombed? Can we expect for a moment, when we have only succeeded, amidst several thousand fragments of corals and shells, in finding a few bones of *aquatic* or *amphibious* animals, that we should meet with a single skeleton of an inhabitant of the land?

Clarence, in his dream, saw, “in the slimy bottom of the deep,”

— a thousand fearful wrecks ;
A thousand men, that fishes gnaw'd upon ;
Wedges of gold, great anchors, heaps of pearl.

Had he also beheld, amid “the dead bones that lay scattered by,” the carcasses of lions, deer, and the other wild tenants of the forest and the plain, the fiction would have been deemed unworthy of the genius of Shakspeare. So daring a disregard of probability and violation of analogy would have been condemned as unpardonable, even where the poet was painting those incongruous images which present themselves to a disturbed imagination during the visions of the night.

But, as fossil mammalian remains have been met with in strata of the more modern periods, it will be desirable to take a rapid view of the contents of suc-

cessive geological formations, and inquire how far they confirm or invalidate the opinions commonly entertained respecting the doctrine of successive development.

In the first place it should be stated, that traces of fossils referable to the animal kingdom make their appearance in strata of as early a date as any in which the impressions of plants have been detected. We are as yet but imperfectly acquainted with the organic remains of the primary fossiliferous formations or those below the carboniferous series ; yet in some of these, as in the limestone of Ludlow, for example, scales and bones of fish have been found.* In these ancient rocks we cannot expect to bring many vertebral remains to light until we have obtained more information respecting the zoophytes and testacea of the same period. The rarer species will scarcely ever be discovered until the more abundant have been found again and again ; and the time may be very distant before we shall succeed in acquiring so extensive a knowledge of the fossil bodies of strata anterior to the coal as to entitle us to attach much importance to the absence of birds and mammalia. In rocks of high antiquity many remains of organic beings have been obliterated by various causes, such as subterranean heat and the percolation of acidulous waters, which have operated during a long succession of ages. The number of fossils which have disappeared from the oldest strata may be conjectured from the fact, that their former existence is in many cases merely revealed to us by the unequal weathering of an exposed face of rock, on which the petrifications stand out in relief.

* Murchison, Silurian System, p. 605.

If we next consider the old red sandstone, we find that entire skeletons of fish have been discovered in it both in Scotland and in the West of England, and Wales, but no well-authenticated instance is recorded of a fossil reptile from this formation.* Neither have any reptilian remains been met with as yet in the incumbent carboniferous group, either in the mountain limestone, or in the shales and sandstones of the coal. The supposed saurian teeth found by Dr. Hibbert in carboniferous strata, near Edinburgh, have been lately shown by Dr. Agassiz to belong to sauroidal fish, or fish of the highest rank in structure, and approaching more nearly in their osteological characters than any others to true sauriens.

It would nevertheless be rash to conclude, that no mammiferous or saurian animals existed when the carboniferous strata were formed. The small islands with which the ocean was probably interspersed in northern latitudes during the carboniferous period (see p. 203.) may like those of the modern Pacific have been entirely destitute of mammalia and large reptiles, yet animals of the same classes may even then have swarmed in continents situated in lower latitudes.

In regard to the absence of birds, they are usually wanting in deposits of all ages, even where fossil animals of the highest order are frequent.†

* Scales of a tortoise nearly allied to *Trionyx*, are stated in the Geol. Trans. second series, vol. iii. part 1. p. 144., to have been found abundantly in the bituminous schists of Caithness, in Scotland, and in the same formation in the Orkneys. These schists have been shown by Professor Sedgwick and Mr. Murchison to be of the age of the old red sandstone. But M. Agassiz has lately decided that the scales in question are those of a fish (see figure of them, plate 16., Geol. Trans., same part).

† See Book III. chap. xv.

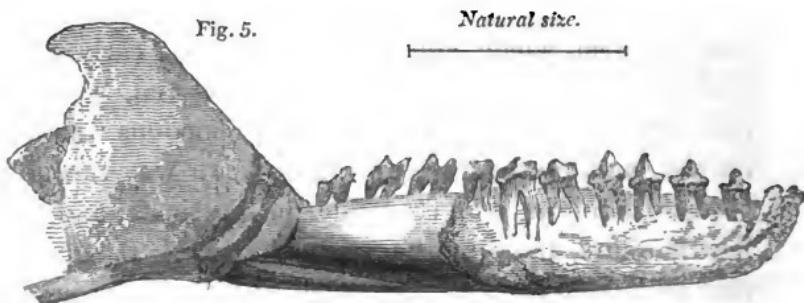
If we pursue the inquiry still farther we come next in chronological order to the secondary formations above the coal, from the magnesian limestone to the chalk inclusive. These rocks comprise the monuments of a long series of ages in which reptiles of every variety of size, form, and structure peopled the earth; so that the whole period, and especially that of the Lias and Oolite, has been sometimes called "the age of reptiles." As there are now mammalia entirely confined to the land, others which, like the bat and vampyre, fly in the air; others, again, of amphibious habits, frequenting rivers, like the hippopotamus, otter, and beaver; others exclusively aquatic and marine, like the seal, whale, and narwal, so in the early ages under consideration, there were terrestrial, winged, and aquatic reptiles. There were iguanodons walking on the land, pterodactyles winging their way through the air, monitors and crocodiles in the rivers, and the ichthyosaurs, and plesiosaurs in the ocean. It appears also that some of these ancient saurians approximated more nearly in their organization to the type of living mammalia than do any of the reptiles now existing.

In the vast range of strata above alluded to, comprising the Lower New Red Sandstone and Magnesian Limestone, the Upper New Red Sandstone and Muschelkalk, the Lias, Oolite, Wealden, Green-Sand and Chalk, only three well-authenticated instances of the occurrence of fossil birds are on record, and one only of fossil mammalia. The birds were discovered first by Mr. Mantell in the Wealden, a great freshwater deposit below the Chalk, and they belong to the order *Grallæ*, or waders *; secondly, in the slate of Glaris in

* Proceedings Geol. Soc. vol. ii. p. 203.

the Swiss Alps, a marine deposit of the Cretaceous era, where the skeleton of a bird nearly entire was detected in 1839, by M. Agassiz; thirdly, the remains of a bird allied to the albatross found lately in the white chalk of England.*

The solitary example of mammalia above alluded to is that of the Stonesfield slate in Oxfordshire, one of the inferior members of the Oolitic series. The remarkable fossils found here consist of the lower jaws of at least two species of small quadrupeds about the size of a mole. Cuvier when he saw one of them (fig. 5.) many years before his death referred it to the Mar-



Thylacotherium Prevostii (Valenciennes). Lower jaw, from the slate of Stonesfield near Oxford. †

* This specimen was obtained by Sir P. Egerton, Bart., and has been since examined by Dr. Buckland and Mr. Owen. The latter informs me that it belonged to the family "Longipennes," of Cuvier, was allied to the albatross, but with longer and stronger legs.

† This figure (No. 5.) is from a drawing by Professor C. Prevost, published Ann. des Sci. Nat., Avril, 1825. The fossil is a lower jaw, adhering by its inner side to the slab of oolite, in which it is sunk. The form of the condyle, or posterior process of the jaw, is convex, agreeing with the mammiferous type, and is distinctly seen, an impression of it being left on the stone, although in this specimen the bone is wanting. The anterior part of the

supial order, stating however, that it differed from all known Carnivora in having ten molar teeth in a row. This opinion, although afterwards called in question by eminent anatomists, has since been corroborated by the observations of MM. Valenciennes and Owen. The last-mentioned naturalist has shown that the bones referred to belonged to an extinct genus, having considerable affinity to a newly-discovered Australian

Fig. 6.



Myrmecobius fasciatus (Waterhouse). Recent from Swan River. Lower jaw of the natural size.*

mammifer, the *Myrmecobius* of Waterhouse, which has nine molar teeth in the lower jaw. (See fig. 6.)

The other mammalian remains from Stonesfield are also referable to an extinct genus, agreeing much more

jaw has been partially broken away, so that the double fangs of the molar teeth are seen fixed in their sockets, the form of the fangs being characteristic of the mammalia. Ten molars are preserved, and the place of an eleventh is believed to be apparent. The enamel of some of the teeth is well preserved.

* A coloured figure of this small and elegant quadruped is given in the Trans. Zool. Soc., vol. ii. pl. 28. It is insectivorous, and was taken in a hollow tree, in a country abounding in ant-hills, ninety miles to the south-east of the mouth of Swan River in Australia. — It is the first living marsupial species known to have nine molar teeth in the lower jaw, and some of the teeth are widely separated from others, one of the peculiarities in the *Thylacotherium* of Stonesfield, which at first induced M. Blainville to refer that creature to the class of reptiles.

nearly in osteological character, and precisely in the number of the teeth, with the opossums. (See fig. 7.)

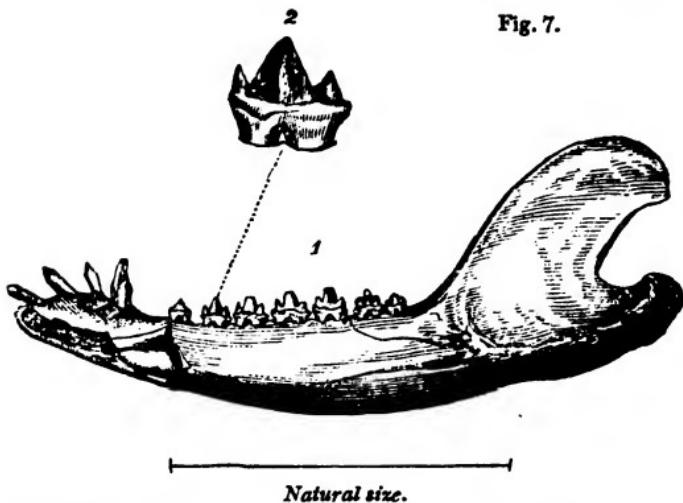


Fig. 7.

Phascolotherium Bucklandi, Owen. (Syn. *Didelphis Bucklandi*, Brod.)
Lower jaw, from Stonesfield.*

1. The jaw magnified twice in length.
2. The second molar tooth magnified six times.

The occurrence of these individuals, the most ancient memorials yet known of the mammiferous type, so low down in the oolitic series, while no other representa-

* This figure (No. 7.) was taken from the original, formerly in Mr. Broderip's collection, and now in the British Museum. It consists of the right half of a lower jaw, of which the inner side is seen. The jaw contains seven molar teeth, one canine, and three incisors, but the end of the jaw is fractured, and traces of the alveolus of a fourth incisor are seen. With this addition, the number of teeth would agree exactly with those of a lower jaw of a didelphia. The fossil is well preserved in a slab of oolitic structure containing shells of *Trigoniæ* and other marine remains. Two or three other similar jaws, besides those above represented, have been procured from the quarries of Stonesfield. — See Broderip, *Zool. Journ.*, vol. iii. p. 408. Owen, *Proceedings Geol. Soc.*, November, 1838,

tives of the same class have yet been found in any other of the inferior or superior secondary strata, is a striking fact, and should serve as a warning to us against hasty generalizations, founded solely on negative evidence. So important an exception to a general rule may be perfectly consistent with the conclusion, that a small number only of mammalia inhabited European latitudes when our secondary rocks were formed; but it seems fatal to the theory of progressive development, or to the notion that the order of precedence in the creation of animals, considered chronologically, has precisely coincided with the order in which they would be ranked according to perfection or complexity of structure.

It has, however, been suggested that the marsupial order to which we have referred the fossil animals of Stonesfield, constitutes the lowest grade in the class Mammalia, and that this order, of which the brain is of more simple form, evinces an inferior degree of intelligence. If, therefore, in the oolitic period the marsupial tribes were the only warm-blooded quadrupeds which had as yet appeared upon our planet, the fact, it is said, confirms the theory which teaches that the creation of the more simple forms in each division of the animal kingdom preceded that of the more complex. But on how slender a support does this important conclusion hang! The Australian continent, so far as it has been hitherto explored, contains no indigenous quadrupeds save those of the marsupial order, with the exception of a few small rodents, while some neighbouring islands to the north, and even southern Africa, in the same latitude as Australia, abound in mammalia of every tribe except the marsupial.

Now we are entirely unable to explain on what

physiological or other laws this singular diversity in the habitations of living mammalia depends. If Europe at the period of the Stonesfield oolite was inhabited by marsupial quadrupeds only, it is still possible that higher orders of mammalia flourished contemporaneously in other lands ; and, secondly, if no other tribes did then exist, we have no right to ascribe such a state of the animal creation to the immature age of the planet or of the animate world. There may be causes with which we are wholly unacquainted, which have stamped so peculiar a character on the recent fauna of Australia, and the general prevalence of an analogous state of things, might give rise every where to a like predominance of the marsupial tribes.

The strata of the Wealden, although of a later date than the oolite of Stonesfield, and although filled with the remains of large reptiles, both terrestrial and aquatic, besides birds and land plants, have not yielded as yet a single marsupial bone. Were we to assume on such scanty data that no warm-blooded quadrupeds were then to be found throughout the northern hemisphere, there would still remain a curious subject of speculation, whether the entire suppression of one important class of vertebrata, such as the mammiferous, and the great development of another, such as the reptilian, implies a departure from fixed and uniform rules governing the fluctuations of the animal world ; such rules, for example, as appear from one century to another to determine the growth of certain tribes of plants and animals in arctic, and of other tribes in tropical regions.

In Australia, New Zealand, and many other parts of the southern hemisphere, where the indigenous land quadrupeds are comparatively few, and of small di-

mensions, the reptiles do not predominate in number or size. The deposits formed at the mouth of an Australian river, within the tropics, might contain the bones of only a few small marsupial animals, which, like those of Stonesfield, might hereafter be discovered with difficulty by geologists; but there would, at the same time, be no megalosauri and other fossil remains, showing that large saurians were plentiful on the land and in the waters, at a time when mammalia were scarce. This example, therefore, affords us no parallel to the state of the animal kingdom, supposed to have prevailed during the secondary periods, when a high temperature pervaded European latitudes.

It may nevertheless be advantageous to inquire how far existing anomalies in the geographical development of distinct classes of vertebrata may be comparable to former conditions of the animal creation brought to light by geology. Now in the Arctic regions, at present, reptiles are small, and sometimes wholly wanting, where birds, large land quadrupeds, and cetacea abound. We meet with bears, wolves, foxes, musk oxen, and deer, walrusses, seals, whales, and narwals, in regions of ice and snow, where the smallest snakes, efts, and frogs are rarely if ever seen.

A still more anomalous state of things presents itself in the southern hemisphere. Even in the temperate zone, between the latitudes 52° and 56° S., as, for example, in Terra del Fuego, as well as in the woody region immediately north of the Straits of Magellan, and in the Falkland Islands, no reptiles of any kind are met with, not even a snake, lizard, or frog; but in these same countries we find the guanaco (a kind of llama), a deer, the punia, a large species of fox, many

small rodentia, besides the seal and otter, together with the porpoise, whale, and other cetacea.

On what grand laws in the animal physiology these remarkable phenomena depend, cannot, in the present state of science, be conjectured; nor could we predict whether any opposite condition of the atmosphere, in respect to heat, moisture, and other circumstances, would bring about a state of animal life which might be called the converse of that above described, namely, a state in which reptiles of every size and order might abound, and mammalia disappear.

The nearest approximation to such a fauna is found in the Galapagos Archipelago. These islands, situated under the equator, and nearly 600 miles west of the coast of Peru, have been called "the land of reptiles," so great is the number of snakes, large tortoises, and lizards, which they support. Among the lizards, the first living species proper to the ocean has been discovered. Yet although some of these islands are from 3000 to 4000 feet high, and one of them 75 miles long, they contain, with the exception of one small mouse, no indigenous mammifer. In the neighbouring sea, however, there are seals, and several kinds of cetacea.*

It may be unreasonable to look for a nearer analogy between the fauna now existing in any part of the globe, and that which we can show to have prevailed when our secondary strata were deposited, because we must always recollect, that a mean annual temperature like that now experienced at the equator, co-existing with the unequal days and nights of European latitudes, was a state of things to which there is now

* Darwin's Journal, chap. xix. Elements of Geol. p. 594.

no counterpart, and must have produced climates wholly distinct from any now experienced in the globe. Consequently, the type of animal and vegetable existence required for such climates, might be expected to deviate almost as widely from those now established, as do the flora and fauna of our tropical differ from those of our arctic regions.

In the Tertiary strata. — The tertiary formations, as before stated, were deposited when the physical geography of the northern hemisphere had been entirely altered. Large inland lakes had become numerous, as in central France and other countries. There were gulfs of the sea, into which considerable rivers emptied themselves, and where strata like those of the Paris basin were accumulated. There were also littoral formations in progress, such as are indicated by the *Faluns* of the Loire, and the English *Crag*.

The proximity, therefore, of large tracts of dry land to the seas and lakes then existing, may, in a great measure, explain why the remains of land animals, so rare in the older strata, are not uncommon in these more modern deposits. Yet even these have sometimes proved entirely destitute of mammiferous relics, for years after they had become celebrated for the abundance of their fossil testacea, fish, and reptiles. Thus the calcaire grossier, a marine limestone of the district round Paris, had afforded to collectors more than 1100 species of shells, besides many zoophytes, echinodermata, and the teeth of fish, before the bones of one or two land quadrupeds were met with in the same rock. The strata called London and plastic clay in England, have been studied for more than half a century, and about 400 species of shells, 50 or more of fish, besides several kinds of chelonian and

saurian reptiles, were known before a single mammifer was detected. At length, in the year 1839, there were found in this formation the remains of a monkey, an opossum, a bat *, and a species of the extinct genus *Hyracotherium*, allied to the pecari or hog tribe.

If we examine the strata above the London clay in England, we first meet with mammiferous remains in the Isle of Wight, in beds also belonging to the Eocene epoch, such as the remains of the *Palæotherium*, *Anoplotherium*, and other extinct quadrupeds, agreeing very closely with those first found by Cuvier, near Paris, in strata of the same age, and of similar fresh-water origin.

Next in the ascending series in Great Britain we arrive at the coralline crag of Suffolk, a marine Miocene stratum, which has yielded three or four hundred species of shells, of which about 20 per cent. are recent, besides many corals, echini, foraminifera, and fish, but as yet no relic decidedly mammalian.

In the shelly sand, provincially termed "Red Crag," in Suffolk, which immediately succeeds the coralline, constituting a newer member of the Miocene series, about 250 species of shells have been recognized, of which about 30 per cent. are recent. They are associated with numerous teeth of fish, but no signs of a warm-blooded quadruped had been detected until 1839, when the teeth of a leopard, bear, hog, and a species of ruminant, were found at Newbourn in Suffolk, under circumstances which leave scarcely any doubt that they were of the age of the Red Crag.†

* Taylor's Annals of Nat. Hist. Nov. 1839.

† See notice by the author and Professor Owen, Taylor's Annals of Nat. Hist. Nov. 1839.

Of a still newer date is the Norwich Crag, a fluviomarine deposit of the Pliocene epoch, containing a mixture of marine, fluviatile, and land shells, of which about 60 per cent. are recent. These beds, since the time of their first investigation, have yielded a supply of mammalian bones of the genera mastodon, elephant, rhinoceros, pig, horse, deer, ox, and others, the bodies of which may have been washed down into the sea by rivers draining land, of which the contiguity is indicated by the occasional presence of terrestrial and freshwater shells.

Fossil quadrupeds. — Until within a few years (1836, 1837), not a single bone of any quadrumanous animal, such as the orang, ape, baboon, and monkey, had been discovered in a fossil state, although so much progress had been made in bringing to light the extinct mammalia of successive tertiary eras, both carnivorous and herbivorous. The total absence of these anthropomorphous tribes among the records of a former world, had led some to believe that the type of organization most nearly resembling the human, came so late in the order of creation, as to be scarcely, if at all, anterior to that of man. That such generalizations were premature, I endeavoured to point out in former editions of this work *, in which I stated that the bones of quadrupeds hitherto met with in tertiary deposits, were chiefly those which frequent marshes, rivers, or the borders of lakes, as the elephant, rhinoceros, hippopotamus, tapir, hog, deer, and ox, while species which live in trees are extremely rare in a fossil state. I also affirmed, that we had as yet no

* See *Principles of Geology*, 1st ed. 1830, vol. i. p. 152., and subsequent editions.

data for determining how great a number of the one kind we ought to find before we have a right to expect a single individual of the other. Lastly, I observed that the climate of the more modern (or Post-Eocene) tertiary periods in England was not tropical, and that in regard to the London clay, of which the crocodiles, turtles, and fossil fruits, implied a climate hot enough for the quadrupedal, we had as yet made too little progress in ascertaining what were the Eocene pachydermata of England, to entitle us to expect to have discovered any quadrupedal of the same date.

Since those remarks were first written, in 1829, a great number of extinct species have been added to our collections of tertiary mammalia, from Great Britain and other parts of the world. At length, between the years 1836 and 1839, a few remains of quadrupedal were found in France and England, India and Brazil. Those of India, belonging to more than one extinct species of monkey, were first discovered near Saharunpore, in lat. 30° N., in tertiary strata, of which the age is not yet determined; the Brazilian fossil, brought from the basin of the Rio das Velhas, about lat. 18° S., is referable to a form now peculiar to America, allied to the genus *Callithrix*, the species being extinct. The skull and other bones met with in the South of France, belong to a gibbon, or one of the tailless apes, which stand next in the scale of organization to the orang. It occurred at Sansan, about forty miles west of Toulouse, in lat. $43^{\circ} 40'$ N., in freshwater strata, probably of the Miocene or middle tertiary period. Lastly, the English quadrupedal occurred in a more ancient stratum than the rest, and at a point more remote from the equator. It belongs to the genus *Macacus*, is an extinct species,

and was found in Suffolk, in lat. 52° *, in the London clay, the fossils of which, such as crocodiles, turtles, shells of the genus nautilus, and many curious fruits, had already led geologists to the conclusion that the climate of that era (the Eocene) was warm and nearly tropical.

The result then, of our inquiry into the evidence of the successive development of the animal and vegetable kingdoms, may be stated in a few words. In regard to *plants*, if we neglect the obscure and ambiguous impressions found in some of the oldest

* The first quadrumanous fossils discovered in India were observed in 1836 in the Sewalik Hills, a lower range of the Himalayan Mountains, by Lieutenants Baker and Durand, by whom their osteological characters were determined (*Journ. of Asiatic Soc. of Bengal*, vol. v. p. 739.), and in the year following, other fossils of the same class were brought to light and described by Capt. Cautley and Dr. Falconer. These were imbedded, like the former, in tertiary strata of conglomerate, sand, marl, and clay, in the Sub-Himalayan Mountains. (*Ibid.* vol. v. p. 379. Nov. 1836, and vol. vi. p. 354. May, 1837.)

The Brazilian quadruped was found, with a great many other extinct species of animals, by a Danish naturalist, Dr. Lund, between the rivers Francisco and Velhas, tributaries of the Parana, in 1837.

The gibbon of the South of France was found by M. Lartet in the beginning of 1837, and determined by M. de Blainville. It occurred near Auch, in the department of Gers, about forty miles west of Toulouse, in freshwater marl, limestone, and sand. They were accompanied by the remains of the mastodon, dinotherium, palæotherium, rhinoceros, gigantic sloth, and other extinct quadrupeds. (*Bulletin de la Soc. Géol. de France*, tom. viii. p. 92.)

The British quadruped was discovered in 1839, by Messrs. William Colchester and Searles Wood, at Kyson, near Woodbridge, in Suffolk, and was referred by Professor Owen to the genus Macacus. (*Mag. of Nat. Hist.* Sept. 1839. *Taylor's Annals of Nat. Hist.*, No. xxiii. Nov. 1839.)

fossiliferous rocks, which can lead to no safe conclusions, we may consider those which characterize the great carboniferous group as the first deserving particular attention. They are by no means confined to the simplest forms of vegetation, as to the cryptogamia; but, on the contrary, belong to all the leading divisions of the vegetable kingdom; some of the more fully developed forms, both of dicotyledons and monocotyledons, having already been discovered, even among the first three or four hundred species brought to light: it is therefore superfluous to pursue this part of the argument farther.

If we then examine the animal remains of the oldest formations, we find bones and skeletons of fish in the old red sandstones, and even in some transition- or primary fossiliferous limestones below it; in other words, we have already vertebrated animals in the most ancient strata, respecting the fossils of which we can be said to possess extensive information.

In regard to birds and quadrupeds, their remains are usually wanting in *marine* deposits of every era, even where interposed freshwater strata contain those fossils in abundance, as in the Paris basin. The secondary strata of Europe are for the most part marine, and there is as yet only one instance of the occurrence of mammiferous fossils in them, individuals of two distinct genera having been found in the slate of Stonesfield, a rock unquestionably of the Oolitic period, and which appears, from several other circumstances, to have been formed near the point where some river entered the sea.

When we examine the tertiary groups, we find in the Eocene or oldest strata of that class the remains of a great assemblage of the highest or mammiferous order,

all of extinct species, and in the Miocene beds, or those of a newer tertiary epoch, other forms, for the most part of lost species, and almost entirely distinct from the Eocene tribes. Another change is again perceived, when we investigate the fossils of still later periods. But in this succession of quadrupeds, we cannot detect any signs of a progressive development of organization,— any clear indication that the Eocene fauna was less perfect than the Miocene, or the Miocene than that of the Older or Newer Pliocene periods.

Recent origin of man.—If, then, the popular theory of the successive development of the animal and vegetable world, from the simplest to the most perfect forms, rests on a very insecure foundation ; it may be asked, whether the recent origin of man lends any support to the same doctrine, or how far the influence of man may be considered as such a deviation from the analogy of the order of things previously established, as to weaken our confidence in the uniformity of the course of nature.

I need not dwell on the proofs of the low antiquity of our species, for it is not controverted by any experienced geologist ; indeed the real difficulty consists in tracing back the signs of man's existence on the earth to that comparatively modern period when species, now his contemporaries, began greatly to predominate. If there be a difference of opinion respecting the occurrence in certain deposits of the remains of man and his works, it is always in reference to strata confessedly of the most modern order ; and it is never pretended that our race co-existed with assemblages of animals and plants, of which *all or even a large proportion of the species* are extinct. From the concurrent testimony of history and tradition, we learn that

parts of Europe, now the most fertile and most completely subjected to the dominion of man, were, less than three thousand years ago, covered with forests, and the abode of wild beasts. The archives of nature are in perfect accordance with historical records; and when we lay open the most superficial covering of peat, we sometimes find therein the canoes of the savage, together with huge antlers of the wild stag, or horns of the wild bull. In caves now open to the day in various parts of Europe, the bones of large beasts of prey occur in abundance; and they indicate that, at periods comparatively modern in the history of the globe, the ascendancy of man, if he existed at all, had scarcely been felt by the brutes.*

No inhabitant of the land exposes himself to so many dangers on the waters as man, whether in a savage or a civilized state †; and there is no animal, therefore, whose skeleton is so liable to become imbedded in lacustrine or submarine deposits: nor can it be said that his remains are more perishable than those of other animals; for in ancient fields of battle, as Cuvier has observed, the bones of men have suffered as little decomposition as those of horses which were buried in the same grave.‡ But even if the more solid parts of our species had disappeared, the impression of their form would have remained engraven on the rocks, as have the traces of the tenderest leaves of plants, and the soft integuments of many animals. Works of art, moreover, composed of the most inde-

* Respecting the probable antiquity assignable to certain human bones and works of art found intermixed with remains of extinct animals in several caves in France, see Book iii. ch. xiv.

† See Book iii. ch. xvi.

‡ Ibid.

structible materials, would have outlasted almost all the organic contents of sedimentary rocks. Edifices, and even entire cities, have, within the times of history, been buried under volcanic ejections, submerged beneath the sea, or engulfed by earthquakes; and had these catastrophes been repeated throughout an indefinite lapse of ages, the high antiquity of man would have been inscribed in far more legible characters on the framework of the globe than are the forms of the ancient vegetation which once covered the islands of the northern ocean, or of those gigantic reptiles which at still later periods peopled the seas and rivers of the northern hemisphere.*

Dr. Prichard has argued that the human race have not always existed on the surface of the earth, because "the strata of which our continents are composed were once a part of the ocean's bed"—"mankind had a beginning, since we can look back to the period when the surface on which they lived began to exist."† This proof, however, is insufficient, for many thousands of human beings now dwell in various quarters of the globe where marine species lived within the times of history, and, on the other hand, the sea now prevails permanently over large districts once inhabited by thousands of human beings. Nor can this interchange of sea and land ever cease while the present causes are in existence. It is conceivable, therefore, that terrestrial species might be older than the continents which they inhabit, and aquatic species of higher antiquity than the lakes and seas which they people.

Doctrine of successive development not confirmed by the admission that man is of modern origin. — It is on

* See Book III. ch. xvi.

† Phys. Hist. of Mankind, vol. ii. p. 594.

other grounds that we are entitled to infer that man is, comparatively speaking, of modern origin ; and if this be assumed, we may then ask whether his introduction can be considered as one step in a progressive system, by which, as some suppose, the organic world advanced slowly from a more simple to a more perfect state ? In reply to this question, it should first be observed, that the superiority of man depends not on those faculties and attributes which he shares in common with the inferior animals, but on his reason, by which he is distinguished from them. When it is said that the human race is of far higher dignity than were any pre-existing beings on the earth, it is the intellectual and moral attributes only of our race, not the animal, which are considered ; and it is by no means clear, that the organization of man is such as would confer a decided pre-eminence upon him, if, in place of his reasoning powers, he was merely provided with such instincts as are possessed by the lower animals.

If this be admitted, it would by no means follow, even if there had been sufficient geological evidence in favour of the theory of progressive development, that the creation of man was the last link in the same chain. For the sudden passage from an irrational to a rational animal is a phenomenon of a distinct kind from the passage from the more simple to the more perfect forms of animal organization and instinct. To pretend that such a step, or rather leap, can be part of a regular series of changes in the animal world, is to strain analogy beyond all reasonable bounds.

Introduction of man, to what extent a change in the system. — But setting aside the question of progressive development, another and a far more difficult one may arise out of the admission that man is comparatively of

modern origin. Is not the interference of the human species, it may be asked, such a deviation from the antecedent course of physical events, that the knowledge of such a fact tends to destroy all our confidence in the uniformity of the order of nature, both in regard to time past and future? If such an innovation could take place after the earth had been exclusively inhabited for thousands of ages by inferior animals, why should not other changes as extraordinary and unprecedented happen from time to time? If one new cause was permitted to supervene, differing in kind and energy from any before in operation, why may not others have come into action at different epochs? Or what security have we that they may not arise hereafter? And if such be the case, how can the experience of one period, even though we are acquainted with all the possible effects of the then existing causes, be a standard to which we can refer all natural phenomena of other periods?

Now these objections would be unanswerable, if adduced against one who was contending for the absolute uniformity throughout all time of the succession of sublunary events—if, for example, he was disposed to indulge in the philosophical reveries of some Egyptian and Greek sects, who represented all the changes both of the moral and material world as repeated at distant intervals, so as to follow each other in their former connexion of place and time. For they compared the course of events on our globe to astronomical cycles; and not only did they consider all sublunary affairs to be under the influence of the celestial bodies, but they taught that on the earth, as well as in the heavens, the same identical phenomena recurred again and again in a perpetual vicissitude.

The same individual men were doomed to be re-born, and to perform the same actions as before ; the same arts were to be invented, and the same cities built and destroyed. The Argonautic expedition was destined to sail again with the same heroes, and Achilles with his Myrmidons to renew the combat before the walls of Troy.

Alter erit tum Tiphys, et altera quæ vehat Argo
Dilectos heroas : erunt etiam altera bella,
Atque iterum ad Trojam magnus mittetur Achilles.*

The geologist, however, may condemn these tenets as absurd, without running into the opposite extreme, and denying that the order of nature has, from the earliest periods, been uniform in the same sense in which we believe it to be uniform at present, and expect it to remain so in future. We have no reason to suppose, that when man first became master of a small part of the globe, a greater change took place in its physical condition than is now experienced when districts, never before inhabited, become successively occupied by new settlers. When a powerful European colony lands on the shores of Australia, and introduces at once those arts which it has required many centuries to mature ; when it imports a multitude of plants and large animals from the opposite extremity of the earth, and begins rapidly to extirpate many of the indigenous species, a mightier revolution is effected in a brief period than the first entrance of a savage horde, or their continued occupation of the country for many

* Virgil, Eclog. iv. For an account of these doctrines, see Dugald Stewart's Elements of the Philosophy of the Human Mind, vol. ii. chap. ii. sect. 4., and Prichard's Egypt. Mythol. p. 177.

centuries, can possibly be imagined to have produced. If there be no impropriety in assuming that the system is uniform when disturbances so unprecedented occur in certain localities, we can with much greater confidence apply the same language to those primeval ages when the aggregate number and power of the human race, or the rate of their advancement in civilization, must be supposed to have been far inferior. In reasoning on the state of the globe immediately before our species was called into existence, we must be guided by the same rules of induction as when we speculate on the state of America in the interval that elapsed between the introduction of man into Asia, the supposed cradle of our race, and the arrival of the first adventurers on the shores of the New World. In that interval, we imagine the state of things to have gone on according to the order now observed in regions unoccupied by man. Even now, the waters of lakes, seas, and the great ocean, which teem with life, may be said to have no immediate relation to the human race — to be portions of the terrestrial system of which man has never taken, nor ever can take, possession ; so that the greater part of the inhabited surface of the planet may remain still as insensible to our presence as before any isle or continent was appointed to be our residence.

If the barren soil around Sydney had at once become fertile upon the landing of our first settlers ; if, like the happy isles whereof the poets have given us such glowing descriptions, those sandy tracts had begun to yield spontaneously an annual supply of grain, we might then, indeed, have fancied alterations still more remarkable in the economy of nature to have attended the first coming of our species into the planet. Or if,

when a volcanic island like Ischia was, for the first time, brought under cultivation by the enterprise and industry of a Greek colony, the internal fire had become dormant, and the earthquake had remitted its destructive violence, there would then have been some ground for speculating on the debilitation of the subterranean forces, when the earth was first placed under the dominion of man. But after a long interval of rest, the volcano bursts forth again with renewed energy, annihilates one half of the inhabitants, and compels the remainder to emigrate. The course of nature remains evidently unchanged; and, in like manner, we may suppose the general condition of the globe, immediately before and after the period when our species first began to exist, to have been the same, with the exception only of man's presence.

The modifications in the system of which man is the instrument, do not, perhaps, constitute so great a deviation from previous analogy as we usually imagine; we often, for example, form an exaggerated estimate of the extent of our power in extirpating some of the inferior animals, and causing others to multiply; a power which is circumscribed within certain limits, and which, in all likelihood, is by no means exclusively exerted by our species.* The growth of human population cannot take place without diminishing the numbers, or causing the entire destruction, of many animals. The larger beasts of prey in particular give way before us, but other quadrupeds of smaller size, and innumerable birds, insects, and plants, which are inimical to our interests, increase in spite of us, some attacking our food, others our raiment and persons,

* See Book III. ch. ix.

and others interfering with our agricultural and horticultural labours. We behold the rich harvest which we have raised with the sweat of our brow devoured by myriads of insects, and are often as incapable of arresting their depredations, as of staying the shock of an earthquake, or the course of a stream of lava.

A great philosopher has observed, that we can command nature only by obeying her laws ; and this principle is true even in regard to the astonishing changes which are superinduced in the qualities of certain animals and plants by domestication and garden culture. I shall point out in the third book that we can only effect such surprising alterations by assisting the development of certain instincts, or by availing ourselves of that mysterious law of their organization, by which individual peculiarities are transmissible from one generation to another.*

It is probable from these and many other considerations, that as we enlarge our knowledge of the system, we shall become more and more convinced, that the alterations caused by the interference of man deviate far less from the analogy of those effected by other animals than is usually supposed.† We are often misled, when we institute such comparisons, by our knowledge of the wide distinction between the instincts of animals and the reasoning power of man ; and we are apt hastily to infer, that the effects of a rational and an irrational species, considered merely as *physical agents*, will differ almost as much as the faculties by which their actions are directed.

It is not, however, intended that a real departure from the antecedent course of physical events cannot

* See Book III. ch. iii.

† Id. chapters v. vi. vii. and ix.

be traced in the introduction of man. If that latitude of action which enables the brutes to accommodate themselves in some measure to accidental circumstances, could be imagined to have been at any former period so great, that the operations of instinct were as much diversified as are those of human reason, it might, perhaps, be contended, that the agency of man did not constitute an anomalous deviation from the previously established order of things. It might then have been said, that the earth's becoming at a particular period the residence of human beings, was an era in the moral, not in the physical world — that our study and contemplation of the earth, and the laws which govern its animate productions, ought no more to be considered in the light of a disturbance or deviation from the system, than the discovery of the satellites of Jupiter should be regarded as a physical event affecting those heavenly bodies. Their influence in advancing the progress of science among men, and in aiding navigation and commerce, was accompanied by no reciprocal action of the human mind upon the economy of nature in those distant planets; and so the earth might be conceived to have become, at a certain period, a place of moral discipline, and intellectual improvement to man, without the slightest derangement of a previously existing order of change in its animate and inanimate productions.

The distinctness, however, of the human from all other species, considered merely as an efficient cause in the physical world, is real; for we stand in a relation to contemporary species of animals and plants widely different from that which other irrational animals can ever be supposed to have held to each other. We modify their instincts, relative numbers, and geo-

graphical distribution, in a manner superior in degree, and in some respects very different in kind, from that in which any other species can affect the rest. Besides, the progressive movement of each successive generation of men causes the human species to differ more from itself in power at two distant periods, than any one species of the higher order of animals differs from another. The establishment, therefore, by geological evidence, of the first intervention of such a peculiar and unprecedented agency, long after other parts of the animate and inanimate world existed, affords ground for concluding that the experience during thousands of ages of all the events which may happen on this globe would not enable a philosopher to speculate with confidence concerning future contingencies.

If, then, an intelligent being, after observing the order of events for an indefinite series of ages, had witnessed at last so wonderful an innovation as this, to what extent would his belief in the regularity of the system be weakened? — would he cease to assume that there was permanency in the laws of nature? — would he no longer be guided in his speculations by the strictest rules of induction? To these questions it may be answered, that, had he previously presumed to dogmatize respecting the absolute uniformity of the order of nature, he would undoubtedly be checked by witnessing this new and unexpected event, and would form a more just estimate of the limited range of his own knowledge, and the unbounded extent of the scheme of the universe. But he would soon perceive that no one of the fixed and constant laws of the animate or inanimate world was subverted by human agency, and that the modifications now introduced for the first

time were the accompaniments of new and extraordinary circumstances, and those not of a *physical* but a *moral* nature. The deviation permitted would also appear to be as slight as was consistent with the accomplishment of the new *moral* ends proposed, and to be in a great degree temporary in its nature, so that, whenever the power of the new agent was withheld, even for a brief period, a relapse would take place to the ancient state of things; the domesticated animal, for example, recovering in a few generations its wild instinct, and the garden-flower and fruit-tree reverting to the likeness of the parent stock.

Now, if it would be reasonable to draw such inferences with respect to the future, we cannot but apply the same rules of induction to the past. We have no right to anticipate any modifications in the results of existing causes in time to come, which are not conformable to analogy, unless they be produced by the progressive development of human power, or perhaps by some other new relations which may hereafter spring up between the moral and material worlds. In the same manner, when we speculate on the vicissitudes of the animate and inanimate creation in former ages, we ought not to look for any anomalous results, unless where man has interfered, or unless clear indications appear of some other *moral* source of temporary derangement.

the great problem of the intensity of aqueous and igneous forces at remote periods.

CHAPTER X.

SUPPOSED INTENSITY OF AQUEOUS AND IGNEOUS FORCES AT REMOTE PERIODS.

Intensity of aqueous causes — Slow accumulation of strata proved by fossils — Rate of denudation can only keep pace with deposition — Erratics, and effects of ice — Deluges and the causes to which they are referred — Supposed universality of ancient deposits — Former intensity of igneous action — Volcanic formations of all geological periods — Plutonic rocks of different ages — Gradual development of subterranean movements — Faults.

Intensity of aqueous causes. — THE great problem considered in the preceding chapters, namely, whether the former changes of the earth made known to us by geology, resemble in kind and degree those now in daily progress, may still be contemplated from several other points of view. We may inquire, for example, whether there are any grounds for the belief entertained by many, that the intensity both of aqueous and of igneous forces, in remote ages, far exceeded that which we witness in our own times.

First, then, as to aqueous causes ; it has been shown in our history of the science, that Woodward did not hesitate, in 1695, to teach that the entire mass of fossiliferous strata contained in the earth's crust, had been deposited in a few months ; and, consequently, as their mechanical and derivative origin was already admitted, the reduction of rocky masses into mud, sand,

and pebbles, the transportation of the same to a distance, and their accumulation elsewhere in regular strata, were all assumed to have taken place with a rapidity unparalleled in modern times. This doctrine was modified by degrees, in proportion as different classes of organic remains, such as shells, corals, and fossil plants, had been studied with attention. Analogy led every naturalist to assume that each full-grown individual of the animal or vegetable kingdom, had required a certain number of months or years for the attainment of maturity, and the perpetuation of its species by generation ; and thus the first approach was made to the conception of a common standard of time, without which there are no means whatever of measuring the comparative rate at which any succession of events has taken place at two distinct periods. This standard consisted of the average duration of the lives of individuals of the same genera or families in the animal and vegetable kingdoms ; and the multitude of fossils dispersed through successive strata, implied the continuance of the same species for many generations. At length the idea that species themselves had had a limited duration, arose out of the observed fact that sets of strata of different ages contained fossils of distinct species. Finally, the opinion became general, that in the course of ages, one assemblage of animals and plants had again and again disappeared, and new tribes had started into life to replace them.

Denudation.—In addition to the proofs derived from organic remains, the forms of stratification led, also, on a full investigation, to the belief that sedimentary rocks had been slowly deposited ; but it was still supposed that *denudation*, or the power of running water, and the waves and currents of the ocean, to strip

off superior strata, and lay bare the rocks below, had formerly operated with a rapidity unparalleled in our own times. These opinions were both illogical and inconsistent, because deposition and denudation are parts of the same process, and what is true of the one must be true of the other. Their speed must be always limited by the same causes, and the conveyance of solid matter to a particular region can only keep pace with its removal from another, so that the aggregate of sedimentary strata in the earth's crust can never exceed in volume the amount of solid matter which has been ground down and washed away by running water. How vast then must be the spaces which this abstraction of matter has left vacant! how far exceeding in dimensions all the valleys, however numerous, and the hollows, however vast, which we can prove to have been cleared out by aqueous erosion! The evidences of the work of denudation are defective, because it is the nature of every destroying cause to obliterate the signs of its own agency; but the amount of reproduction in the form of sedimentary strata must always afford a true measure of the denudation which the earth's surface has undergone.

Erratics. — The next phenomenon to which advocates of the excessive power of running water in times past have appealed, is the enormous size of the blocks called *erratic*, which lie scattered over the northern parts of Europe and North America. Unquestionably a large proportion of these blocks have been transported far from their original position, for between them and the parent rocks we now find, not unfrequently, deep seas and valleys intervening, or hills more than a thousand feet high. To explain the present situation of such travelled fragments, a deluge

of mud has been imagined by some to have come from the north, bearing along with it sand, gravel, and stony fragments, some of them hundreds of tons in weight. This flood, in its transient passage over the continents, dispersed the boulders irregularly over hill, valley, and plain, or forced them along over a surface of hard rock, so as to polish it and leave it indented with parallel scratches and grooves, — such markings as are still visible in the rocks of Scandinavia, Scotland, Canada, and many other countries.

There can be no doubt that the myriads of angular and rounded blocks above alluded to cannot have been borne along by ordinary rivers or marine currents, so great is their volume and weight, and so clear are the signs, in many places, of time having been occupied in their successive deposition; for they are often distributed at various depths through heaps of regularly stratified sand and gravel. No waves of the sea raised by earthquakes, nor the bursting of lakes dammed up for a time by landslips or by avalanches of snow, can account for the observed facts; but I shall endeavour to show, in the third chapter of the next book, that a combination of existing causes may have conveyed erratics into their present situations.

The causes which will be referred to are, first, the carrying power of ice; secondly, that of running water; thirdly, the upward movement of the bed of the sea, converting it gradually into land. Without entering at present into any details respecting these causes, I may mention that the transportation of blocks by ice is now simultaneously in progress in the cold and temperate latitudes, both of the northern and southern hemisphere, as, for example,

on the coasts of Canada and Gulf of St. Lawrence, and also in South Georgia, Patagonia, and Chili. In those regions the uneven bed of the ocean is becoming strewed over with ice-drifted fragments, which have either stranded on shoals, or been dropped in deep water by melting bergs. The entanglement of boulders in drift ice will also be shown to occur annually in North America, and these stones, when firmly frozen into ice, wander year after year from Labrador to the St. Lawrence, and reach points of the western hemisphere farther south than any part of Great Britain.

The general absence of erratics in the warmer parts of the equatorial regions of Asia, Africa, and America, confirms the same views. As to the polishing and grooving of hard rocks, it has lately been ascertained that glaciers give rise to these effects: when pushing forward sand, pebbles, and rocky fragments, and causing them to grate along the bottom. Nor can there be any doubt that icebergs, when they run aground on the floor of the ocean, imprint similar marks upon it.

It is unnecessary, therefore, to refer to deluges, or even to speculate on the former existence of a climate more severe than that now prevailing in the western hemisphere, to explain the geographical distribution of most of the European erratics.

Deluges.—As deluges have been often alluded to, I shall say something of the causes which may be supposed to give rise to these grand movements of water. Geologists who believe that mountain-chains have been thrown up suddenly at many successive epochs, imagine that the waters of the ocean may be raised by these convulsions, and then break in terrific waves upon the land, sweeping over whole continents, hollow-

ing out valleys, and transporting sand, gravel, and erratics, to great distances. The sudden rise of the Alps or Andes, it is said, may have produced a flood even subsequently to the time when the earth became the residence of man. But it seems strange that none of the writers who have indulged their imaginations in conjectures of this kind, should have ascribed a deluge to the sudden conversion of part of the unfathomable ocean into a shoal rather than to the rise of mountain-chains. In the latter case, the mountains themselves could do no more than displace a certain quantity of atmospheric air, whereas, the instantaneous formation of the shoal would displace a vast body of water, which being heaved up to a great height might roll over and permanently submerge a large portion of a continent.

If we restrict ourselves to combinations of causes at present known, it would seem that the two principal sources of extraordinary inundations are, first, the escape of the waters of a large lake raised far above the sea; and, secondly, the pouring down of a marine current into lands depressed below the mean level of the ocean.

As an example of the first of these cases, we may take Lake Superior, which is more than 400 geographical miles in length and about 150 in breadth, having an average depth of from 500 to 900 feet. This vast body of freshwater is raised no less than 600 feet above the level of the ocean; and the lowest part of the barrier which separates the south-western boundary of the lake from those streams which flow into the head waters of the Mississippi is not more than 600 feet high. If, therefore, a series of partial subsidences should lower the barrier 600 feet, any subsequent

rending or depression, even of a few yards at a time, would allow the sudden escape of vast floods of water into a hydrographical basin of enormous extent. If the event happened in the dry season, when the ordinary channels of the Mississippi and its tributaries are in a great degree empty, the inundation might not be considerable, but if in the flood-season, a region capable of supporting a population of many millions might be suddenly submerged. But even this event would be insufficient to cause a violent rush of water, and to produce those effects usually called diluvial, for the difference of level between Lake Superior and the Gulf of Mexico is no more than 600 feet in a distance of 1800 miles. Nor would it be consistent with analogy to calculate on the entire removal of the barrier at once. We ought rather to expect it to sink by a series of successive subsidences, or to be fissured again and again, and the channel of discharge to be widened and deepened gradually as the rushing waters escape.

The second case before adverted to is where there are large tracts of dry land beneath the mean level of the ocean. It seems, after much controversy, to be at length a settled point, that the Caspian is really 108 feet lower than the Black Sea. As the Caspian covers an area about equal to that of Spain, and as its shores are in general low and flat, there must be many thousand square miles of country less than 108 feet above the level of that inland sea, and consequently depressed below the Black Sea and Mediterranean. This area includes the site of the populous city of Astrakhan and other towns. Into this region the ocean would pour its waters, if the land now intervening between the Sea of Azof and the Caspian should subside. Yet, even

if this event should occur, it is most probable that the submergence of the whole region would not be accomplished simultaneously, but by a series of minor floods, the sinking of the barrier being gradual.*

Supposed universality of ancient deposits.—The next fallacy which has helped to perpetuate the doctrine that the operations of water were on a grander scale in ancient times, is founded on the indefinite areas

* It has been suspected ever since the middle of the last century, that the Caspian was lower than the ocean, it being known that in Astrakhan the mercury in the barometer generally stands above thirty inches. In 1811, MM. Engelhardt and Parrot attempted to determine the exact amount of difference by a series of levellings and barometrical measurements across the isthmus at two different places near the foot of Mount Caucasus. The result of their operations led them to the opinion that the Caspian was more than 300 feet below the Black Sea. But the correctness of the observations having afterwards been called in question, M. Parrot revisited the ground in 1829 and 1830, and inferred from new levellings, that the mouth of the Don was between three and four feet lower than that of the Wolga; in other words, that the sea of Azof which communicates with the Black Sea was actually lower than the Caspian! Other statements, no less contradictory, having been made by other observers, the Russian government at length directed the Academy of St. Petersburg, to send an expedition in 1836, to decide the point by a trigonometrical survey, from which it appeared that the Caspian is 101 Russian, or 108 English feet lower than the Black Sea. (For authorities see Journ. Roy. Geograph. Soc. vol. viii. p. 135.)

According to the researches of Mr. G. Moore and Mr. Beek made in 1837, the level of the Dead Sea was estimated by the temperature of boiling water to be 500 feet below the level of the Mediterranean, a result confirmed by the barometrical experiments of Professor Schubert of Munich, according to which the difference of level is 598 feet. The last-mentioned traveller also states, that the Lake of Tiberias is 500 feet below the Mediterranean. (Journ. Roy. Geograph. Soc. vol. viii. p. 250.)

over which homogeneous deposits were supposed to extend. No modern sedimentary strata, it is said, equally identical in mineral character and fossil contents, can be traced continuously from one quarter of the globe to another. But the first propagators of these opinions were very slightly acquainted with the inconstancy in mineral composition of the ancient formations, and equally so of the wide spaces over which the same kind of sediment is now actually distributed by rivers and currents in the course of centuries. The persistency of character in the older series was exaggerated, its extreme variability in the newer was assumed without proof. In the chapter which treats of river-deltas and the dispersion of sediment by currents, and in the description of reefs of coral now growing over areas many hundred miles in length, I shall have opportunities of convincing the reader of the danger of hasty generalizations on this head.

In regard to the imagined universality of particular rocks of ancient date, it was almost unavoidable that this notion, when once embraced, should be perpetuated; for the same kinds of rock have occasionally been reproduced at successive epochs: and when once the agreement or disagreement in mineral character alone was relied on as the test of age, it followed that similar rocks, if found even at the antipodes, were referred to the same era, until the contrary could be shown.

Now it is usually impossible to combat such an assumption on geological grounds, so long as we are imperfectly acquainted with the order of superposition and the organic remains of these same formations. Thus, for example, a group of red marl and red sandstone, containing salt and gypsum, being interposed in

England between the Lias and the Coal, all other red marls and sandstones, associated some of them with salt, and others with gypsum, and occurring not only in different parts of Europe, but in Peru, India, the salt deserts of Asia, those of Africa — in a word, in every quarter of the globe, were referred to one and the same period. The burden of proof was not supposed to rest with those who insisted on the identity in age of all these groups — their identity in mineral composition was thought sufficient. It was in vain to urge as an objection the improbability of the hypothesis which implies that all the moving waters on the globe were once simultaneously charged with sediment of a red colour.

But the rashness of pretending to identify, in age, all the red sandstones and marls in question, has at length been sufficiently exposed, by the discovery that, even in Europe, they belong decidedly to many different epochs. It is already ascertained, that the red sandstone and red marl containing the rock-salt of Cardona in Catalonia, may be referred to the period of our Chalk and Green Sand. It is also known that certain red marls and variegated sandstones, in Auvergne, which are undistinguishable in mineral composition from the New Red Sandstone of English geologists, belong, nevertheless, to the Eocene period : and, lastly, the gypseous red marl of Aix, in Provence, formerly supposed to be a marine secondary group, is now acknowledged to be a tertiary freshwater formation.

Nor was the nomenclature commonly adopted in geology without its influence in perpetuating the erroneous doctrine of universal formations. Such names for example, as Chalk, Green Sand, Oolite, Red Marl, Coal, and others, were given to some of the principal

fossiliferous groups in consequence of mineral peculiarities which happened to characterize them in the countries where they were first studied. When geologists had at length shown, by means of fossils and the order of superposition, that other strata, entirely dissimilar in colour, texture, and composition, were of contemporaneous date, it was thought convenient still to retain the old names. That these were often inappropriate was admitted, but the student was taught to understand them in no other than a chronological sense, so that the Chalk might not be a white cretaceous rock, but a hard dolomitic limestone, as in the Pyrenees, or a black slate, as at Glaris and the Lake of Thun, in Switzerland. In like manner the Green Sand, it was said, might in some places be represented by red sandstone, red marl, salt, and gypsum, as in the north of Spain. So the oolitic texture was declared to be rather an exception than otherwise to the general rule in rocks of the Oolitic period; and it often became necessary to affirm that no particle of carbonaceous matter could be detected in districts where the true Coal series abounded. In spite of every precaution the habitual use of this language could scarcely fail to instil into the mind of the pupil an idea that chalk, coal, salt, red marl, or the oolitic structure were far more widely characteristic of the rocks of a given age than was really the case.

There is still another cause of deception disposing us to ascribe a more limited range to the newer sedimentary formations as compared to the older, namely, the very general concealment of the newer strata beneath the waters of lakes and seas, and the wide exposure above water of the more ancient. The Chalk, for example, now seen stretching for thousands of

miles over different parts of Europe has become visible to us by the effect, not of one, but of many distinct series of subterranean movements. Time has been required, and a succession of geological periods, to raise it above the waves in so many regions; and if calcareous rocks of the Eocene or Miocene periods have been formed, as homogeneous in mineral composition throughout equally extensive regions, it may require convulsions as numerous as all those which have occurred since the origin of the Chalk to bring them up within the sphere of human observation. Hence the rocks of more modern periods may appear partial, as compared to those of remoter eras, not because of any original inferiority in their extent, but because there has not been sufficient time since their origin for the development of a great series of elevatory movements.

In regard, however, to one of the most important characteristics of sedimentary rocks, their organic remains, many naturalists of high authority suspect that the same species of fossils are more uniformly distributed through formations of high antiquity than in those of more modern date, and that distinct zoological and botanical provinces, as they are called, which form so striking a feature in the living creation, were not established at remote eras. Thus the plants of the Coal, the shells and trilobites of the Silurian rocks, and the ammonites of the Oolite, have been supposed to have a wider geographical range than any living species of trees, crustaceans, or mollusks.

It seems by no means unlikely that this opinion will prove, to a certain extent, well founded, but no comparison has yet been made of a large assemblage of fossils from two very distant points with sufficient

minuteness to entitle us to pronounce on the specific identity of the whole. In the theory of climate proposed in the seventh and eighth chapters, we have seen how the altered position of sea and land might render the temperature of the globe more uniform, in which case the fauna and flora of the earth would be less diversified than now.

Supposed former intensity of igneous action. — In reasoning on the igneous as well as the aqueous forces, geologists have been fain to represent nature at remote epochs as having been prodigal of violence and parsimonious of time. Now although it is less easy to determine the relative ages of the volcanic than of the fossiliferous formations, it is undeniable that igneous rocks have been produced at all geological periods, or as often as we find distinct deposits marked by peculiar animal and vegetable remains. It can be shown that rocks commonly called trappean have been injected into fissures, and ejected at the surface, both before and during the deposition of the Carboniferous series, and at the time when the Magnesian Limestone, and when the Upper New Red Sandstone were formed, or when the Lias, Oolite, Green Sand, Chalk, and the several tertiary groups newer than the Chalk, originated in succession. Nor is this all; distinct volcanic products may be referred to the subordinate divisions of each period, such as the Carboniferous, as in the county of Fife, in Scotland, where certain masses of contemporaneous trap are associated with the Lower, others with the Upper Coal-measures. And if one of these masses is more minutely examined, we find it to consist of the products of a great many successive outbursts, by which scoriae and lava were again and again emitted, and afterwards consolidated, then fissured, and

finally traversed by melted matter constituting what are called dikes. As we enlarge, therefore, our knowledge of the ancient rocks formed by subterranean heat, we find ourselves compelled to regard them as the aggregate effects of innumerable eruptions, each of which may have been comparable in violence to those now experienced in volcanic regions.

It may indeed be said that we have as yet no data for estimating the relative volume of matter simultaneously in a state of fusion at two given periods, as if we were to compare the columnar basalt of Staffa and its environs with the lava poured out in Iceland in 1783; but for this very reason it would be rash and unphilosophical to assume an excess of ancient as contrasted with modern outpourings of melted matter at particular periods of time.* It would be still more presumptuous to take for granted that the more deep-seated effects of subterranean heat surpassed at remote eras the corresponding effects of internal heat in our own times. Certain porphyries and granites, and all the rocks commonly called plutonic, are now generally supposed to have resulted from the slow cooling of materials fused and solidified under great pressure; and we cannot doubt that beneath existing volcanos there are large spaces filled with melted stone, which must for centuries remain in an incandescent state, and then cool and become hard and crystalline when the subterranean heat shall be exhausted. That lakes of lava are continuous for hundreds of miles beneath the Chilian Andes, seems established by observations made in the year 1835.

Now, wherever the fluid contents of such reservoirs

* See Vol. II. p. 258.

are poured out successively from craters in the open air or at the bottom of the sea, the matter so ejected may afford evidence by its arrangement of having originated at different periods; but if the subterranean residue after the withdrawal of the heat be converted into crystalline or plutonic rock, the entire mass will seem to have been formed at once, however countless the ages required for its fusion and subsequent refrigeration. As the idea that all the granite in the earth's crust was produced simultaneously, and in a primitive state of the planet, has now been universally abandoned; so the suggestion above adverted to may put us on our guard against too readily adopting another opinion, namely, that each large mass of granite was generated in a brief period of time.

The doctrine of some modern writers of authority that crystalline rocks, such as granite, gneiss, micaschist, quartzite, and others, were produced in the greatest abundance in the earlier ages of the planet, and that their formation has ceased altogether in our own times, will be controverted in the thirteenth chapter.

Gradual development of subterranean movements.—The extreme violence of the subterranean forces in remote ages has been often inferred from the fact that the older rocks are more fractured and dislocated than the newer. But what other result could we have anticipated if the quantity of movement had been always equal in equal periods of time? Time must in that case multiply the derangement of strata in the ratio of their antiquity. Indeed, the numerous exceptions to the above rule which we find in nature, present at first sight the only objection to the hypothesis of uniformity. For the more ancient formations remain in many places horizontal, while in others

much newer strata are curved and vertical. This apparent anomaly, however, will be seen in the next chapter to depend on the irregular manner in which the volcanic and subterranean agency affect different parts of the earth in succession, being often renewed again and again in certain areas, while others remain during the whole time at rest.

That the more impressive effects of subterranean power, such as the upheaval of mountain-chains, are due to multiplied convulsions of moderate intensity rather than to a few paroxysmal explosions, will be naturally inferred, when the gradual and intermittent development of volcanic eruptions in times past is once admitted. It is no longer disputed that these eruptions have their source in the same causes as those to which earthquakes and the permanent rise and fall of land are due; the admission, therefore, that one of the two volcanic or subterranean processes has gone on gradually, draws with it the conclusion that the effects of the other have been elaborated by slow degrees.

Faults.—The same reasoning is applicable to great faults, or those striking instances of the upthrow or downthrow of large masses of rock, which have been often thought to imply tremendous catastrophes wholly foreign to the ordinary course of nature. Thus we have in England a fault, in which the vertical displacement is between 600 and 1000 feet, and the horizontal extent of the movement thirty miles or more, the width of the fissure since filled up with rubbish varying from ten to fifty feet. But when we inquire into the proofs of the mass having risen or fallen suddenly on the one side of this great rent several hundred feet above or below the rock with which it was once continuous on the other side, we find the evidence defec-

tive. There are grooves, it is said, and scratches on the rubbed and polished walls, which have often one common direction, favouring the theory that the movement was accomplished by a single stroke, and not by a series of interrupted movements. But, in fact, the *striæ* are not always parallel in such cases, but often irregular, and sometimes the stones and earth which are in the middle of the fault or fissure have been polished and striated by friction, showing that there have been slidings subsequent to the first introduction of the fragmentary matter. Nor should we forget that the last movement must always tend to obliterate the signs of previous trituration, so that neither its instantaneousness nor the uniformity of its direction can be inferred from the parallelism of the *striæ* that have been last produced.

When rocks have been once fractured, and freedom of motion communicated to detached portions of them, these will naturally continue to yield in the same direction, if the process of upheaval or of undermining be repeated again and again. The incumbent mass will always give way along the lines of least resistance, or where it was formerly rent asunder. Probably, the effects of reiterated movement, whether upward or downward, in a fault, may be undistinguishable from those of a single and instantaneous rise or subsidence, and the same may be said of the rising or falling of continental masses, such as Sweden or Greenland, which we know to take place slowly and insensibly.

The difficulty of reducing within narrow limits the quantity of time which may have elapsed during the origin of great faults and mountain-chains will be better understood, when the reader has perused the concluding pages of the twelfth chapter.

CHAPTER XI.

DOCTRINE OF ALTERNATE PERIODS OF REPOSE AND CONVULSION, AND OF SUDDEN REVOLUTIONS IN THE ANIMATE WORLD, CONTROVERTED.

Observed facts in which this doctrine has originated — These may be equally explained by supposing a uniform and uninterrupted series of changes in the animate and inanimate world — Threefold consideration of this subject; first, in reference to the living creation, extinction of species, and origin of new animals and plants; secondly, in reference to the changes produced in the earth's crust by the continuance of subterranean movements in certain areas, and their transference after long periods to new areas; thirdly, in reference to the laws which govern the formation of fossiliferous strata, and the shifting of the areas of sedimentary deposition — Concluding remarks on the combined influence of all these modes and causes of change in producing breaks and chasms in the chain of records — These breaks independent both of general and local catastrophes, and of crises in the animate world.

Origin of the doctrine of alternate periods of repose and disorder. — It has been truly observed, that when we arrange the fossiliferous formations in chronological order, they constitute a broken and defective series of monuments: we pass, without any intermediate gradations, from systems of strata which are horizontal to other systems which are highly inclined, from rocks of peculiar mineral composition to others which have a character wholly distinct, — from one assemblage of organic remains to another, in which frequently all the species, and most of the genera, are different. These

violations of continuity are so common, as to constitute the rule rather than the exception, and they have been considered by many geologists as conclusive in favour of sudden revolutions in the inanimate and animate world. According to the speculations of some writers, there have been in the past history of the planet alternate periods of tranquillity and convulsion, the former enduring for ages, and resembling that state of things now experienced by man; the other brief, transient, and paroxysmal, giving rise to new mountains, seas, and valleys, annihilating one set of organic beings, and ushering in the creation of another.

It will be the object of the present chapter to demonstrate, that these theoretical views are not borne out by a fair interpretation of geological monuments. It is true that in the solid framework of the globe, we have a chronological chain of natural records, and that many links in this chain are wanting, but a careful consideration of all the phenomena will lead to the opinion that the series was originally defective,—that it has been rendered still more so by time—that a great part of what remains is inaccessible to man, and even of that fraction which is accessible nine tenths are to this day unexplored.

How the facts may be explained by assuming a uniform series of changes.—The readiest way, perhaps, of persuading the reader that we may dispense with great and sudden revolutions in the geological order of events, is by showing him how a regular and uninterrupted series of changes in the animate and inanimate world may give rise to such breaks in the sequence, and such unconformability of stratified rocks, as are usually thought to imply convulsions and cata-

trophes. It is scarcely necessary to state, that the assumed order of events must be in harmony with all the conclusions legitimately drawn by geologists from the structure of the earth, and must be equally in accordance with the changes observed by man to be now going on in the living and inorganic creation. It may be necessary in the present state of science to supply some part of the assumed course of nature hypothetically; but if so, this must be done without any violation of probability, and always consistently with the analogy of what is known both of the past and present economy of our system. Although the discussion of so comprehensive a subject must carry the beginner far beyond his depth, it will also, it is hoped, stimulate his curiosity and prepare him to read with advantage some elementary treatise on geology, and lead him to perceive the bearing on that science of the changes now in progress on the earth. At the same time it may be useful in teaching him to understand the intimate connexion between the second and third books of this work, the former of which is occupied with the changes of the inorganic, the latter with those of the organic creation.

In pursuance, then, of the plan above proposed, I shall consider in this chapter, first, what may be the course of fluctuation in the animate world; secondly, the mode in which subterranean movements affect the earth's crust in the lapse of ages; and, thirdly, the laws which regulate the deposition of sediment.

UNIFORMITY OF CHANGE CONSIDERED FIRST IN REFERENCE TO THE LIVING CREATION.

First, in regard to the vicissitudes of the living creation, all are agreed that the sedimentary strata

found in the earth's crust are divisible into a variety of groups, more or less dissimilar in their organic remains and mineral composition. The conclusion universally drawn from the study and comparison of these fossiliferous groups is this, that at successive periods, distinct tribes of animals and plants have inhabited the land and waters, and that the organic types of the newer formations are more analogous to species now existing, than those of more ancient rocks. If we then turn to the present state of the animate creation, and inquire whether it has now become fixed and stationary, we discover that, on the contrary, it is in a state of continual flux — that there are many causes in action which tend to the extinction of species, and which are conclusive against the doctrine of their unlimited durability. But natural history has been successfully cultivated for so short a period, that a few examples only of local, and perhaps but one of absolute extirpation can as yet be proved, and these only where the interference of man has been conspicuous. It will nevertheless appear evident, from the facts and arguments detailed in the third book (from the fifth to the tenth chapters inclusive) that man is not the only exterminating agent; and that, independently of his intervention, the annihilation of species is promoted by the multiplication and gradual diffusion of every animal or plant. It will also appear in the same book, that every alteration in the physical geography and climate of the globe cannot fail to have the same tendency. If we proceed still further, and inquire whether new species are substituted from time to time for those which die out, and whether there are certain laws appointed by the Author of Nature, to regulate such new creations, we find that the period

of human observation is as yet too short to afford data for determining so weighty a question. All that can be done is to show, that the successive introduction of new species may be a constant part of the economy of the terrestrial system, without our having any right to expect that we should be in possession of direct proof of the fact. The appearance again and again of new species may easily have escaped detection, since the numbers of known animals and plants have augmented so rapidly within the memory of persons now living, as to have doubled in some classes, and quadrupled in others. It will also be remarked in the sequel (Book III. Chap. xi.), that it must always be more easy if species proceed originally from single stocks, to prove that one which formerly abounded in a given district has ceased to be, than that another has been called into being for the first time. If, therefore, there be as yet only one unequivocal instance of extinction, namely, that of the dodo, it is scarcely reasonable as yet to hope that we should be cognizant of a single instance of the first appearance of some new species.

Recent origin of man, and gradual approach in the tertiary fossils of successive periods from an extinct to the recent fauna. — The geologist, however, if required to advance some fact which may lend countenance to the opinion that in the most modern times, that is to say, after the greater part of the existing fauna and flora were established on the earth there has still been a new species superadded, may point to man himself as furnishing the required illustration, — for man must be regarded by the geologist as a creature of yesterday, not merely in reference to the past history of the organic world, but also in relation

to that particular state of the animate creation of which he forms a part. The comparatively modern introduction of the human race is proved by the absence of the remains of man and his works, not only from all strata containing a certain proportion of fossils of extinct species, but even from a large part of the newest strata, in which all the fossil individuals are referable to species still living.

To enable the reader to appreciate the full force of this evidence, I shall give a slight sketch of the information which we have obtained from the more modern strata, respecting the fluctuations of the animate world in times immediately antecedent to the appearance of man.

In tracing the series of fossiliferous formations from the most ancient to the more modern, the first deposits in which we meet with assemblages of organic remains, having a near analogy to the fauna of certain parts of the globe in our own time, are those commonly called tertiary. Even in the Eocene, or oldest subdivision of these tertiary formations, some few of the testacea belong to existing species, although almost all of them, and apparently all the associated vertebrata, are now extinct. These Eocene strata are succeeded by a great number of more modern deposits, which depart gradually in the character of their fossils from the Eocene type, and approach more and more to that of the living creation. In the present state of science, it is chiefly by the aid of shells that we are enabled to arrive at these results, for of all classes the testacea are the most generally diffused in a fossil state, and may be called the medals principally employed by nature in recording the chronology of past events. In the Miocene deposits,

which succeed next to the Eocene, we begin to find a considerable number, although still a minority, of recent species, intermixed with some fossils common to the preceding epoch. We then arrive at the Pliocene strata, in which species now contemporary with man begin to preponderate, and in the newest of which nine tenths of the fossils agree with species still inhabiting the neighbouring sea.

In thus passing from the older to the newer members of the tertiary system we meet with many chasms, but none which separate entirely, and by a broad line of demarcation, one state of the organic world from another. There are no signs of an abrupt termination of one fauna and flora, and the starting into life of new and wholly distinct forms. Although we are far from being able to demonstrate geologically an insensible transition from the Eocene to the recent fauna, yet we may affirm that the more we enlarge and perfect our survey of Europe the more nearly do we approximate to such a continuous series, and the more gradually are we conducted from times when many of the genera and nearly all the species were extinct, to those in which scarcely a single species flourished which we do not know to exist at present.

The great physical revolutions which the surface of Europe has undergone, within the times above adverted to, were spoken of in the description of the map of Europe (p. 211.). Changes, of a similar kind, continued down to a period when the recent testacea predominated to the almost entire exclusion of the extinct. Thus we observe in Sicily a lofty table-land and hills, sometimes rising to the height of 3000 feet, capped with a limestone, in which nine tenths of the fossil testacea are specifically identical with those now

inhabiting the Mediterranean. These calcareous and other argillaceous strata of the same age are intersected by deep valleys which have been gradually formed by denudation, but have not varied materially in width or depth since Sicily was first colonized by the Greeks. The limestone, moreover, which is of so late a date in geological chronology, was quarried for building those ancient temples of Girgenti and Syracuse, of which the ruins carry us back to a remote era in human history. If we are lost in conjectures when speculating on the ages required to lift up these formations to the height of several thousand feet above the sea, how much more remote must be the era when the same rocks were gradually formed beneath the waters?

Post-tertiary formations anterior to man.—Neither in the Sicilian formation above mentioned, nor in any others in which a slight per-cent-age of existing species occur, have any remains of man or his works been as yet detected. It is still more remarkable that deposits of a later date, which may be called post-tertiary (the fossils which they contain agreeing entirely with species of the neighbouring sea), exhibit no memorials of the human race, or of articles fabricated by the hand of man. Some of these strata pass by the name of "raised beaches," occurring at moderate elevations on the coasts of England, Scotland, and Ireland. Other examples are met with on a more extended scale in Scandinavia, as at the height of 200 feet at Uddevalla in Sweden, and at twice that elevation, near Christiania, in Norway, also at an altitude of 600 or 700 feet, in places farther north. They consist of beds of sand and clay, filling hollows in a district of granite and gneiss, and they must closely resemble the accumulations of shelly matter now in progress at the bottom

of the Norwegian fiords. The rate at which the land is now rising in Scandinavia is far too irregular in different places to afford a safe standard for estimating the minimum of time required for the upheaval of the fundamental granite, and its marine shelly covering, to the height of so many hundred feet; but according to the greatest average of five or six feet in a century, the period required would be very considerable, and the whole of it, as well as the antecedent epoch of submergence, seems to have preceded the introduction of man, at least into these parts of the earth.

There are other post-tertiary formations of fluviatile origin, in the centre of Europe, in which the absence of human remains is perhaps still more striking, because, when formed, they must have been surrounded by dry land. I allude to the silt or *loess* of the basin of the Rhine, which must have gradually filled up the great valley of that river since the time when its waters, and the contiguous lands, were inhabited by the existing species of freshwater and terrestrial mollusks. Showers of ashes, thrown out by some of the last eruptions of the Eifel volcanos, fell during the deposition of this fluviatile silt, and were interstratified with it. But these volcanos became exhausted, the valley was re-excavated through the silt, and again reduced to its present form before the period of human history. The study, therefore, of this shelly silt reveals to us the history of a long series of events, which occurred after the testacea now living inhabited the land and rivers of Europe, and the whole terminated without any signs of the coming of man into that part of the globe.

To conclude, it appears that, in going back from the recent to the Eocene period, we are carried by many

successive steps from the fauna now contemporary with man to an assemblage of fossil species wholly different from those now living. In this retrospect we have not yet succeeded in tracing back a perfect transition from the recent to an extinct fauna; but there are so many species in common to the groups which stand next in succession as to show that there is no great chasm, no signs of a crisis when one class of organic beings was annihilated to give place suddenly to another. This analogy, therefore, derived from a period of the earth's history which can best be compared with the present state of things, and more thoroughly investigated than any other, leads to the conclusion that the extinction and creation of species has been and is the result of a slow and gradual change in the organic world.

UNIFORMITY OF CHANGE CONSIDERED, SECONDLY, IN REFERENCE TO SUBTERRANEAN MOVEMENTS.

To pass on to another of the three topics before proposed for discussion, the reader will find, in the account given in the second book of the earthquakes recorded in history, that certain countries have, from time immemorial, been rudely shaken again and again, while others, comprising by far the largest part of the globe, have remained, to all appearance, motionless. In the regions of convulsion rocks have been rent asunder, the surface has been forced up into ridges, chasms have opened, or the ground throughout large spaces has been permanently lifted up above or let down below its former level. In the regions of tranquillity some areas have remained at rest, but others have been ascertained by a comparison of measure-

ments, made at different periods, to have risen by an insensible motion, as in Sweden, or to have subsided very slowly, as in Greenland. That these same movements, whether ascending or descending, have continued for ages in the same direction has been established by geological evidence. Thus, we find both on the east and west coast of Sweden, that ground which formerly constituted the bottom of the Baltic and of the ocean has been lifted up to an elevation of several hundred feet above high-water mark. The rise within the historical period has not amounted to many yards, but the greater extent of antecedent upheaval is proved by the occurrence in inland spots, several hundred feet high, of deposits filled with fossil shells of species now living either in the ocean or the Baltic.

To detect proofs of slow and gradual subsidence must in general be more difficult; but the theory which accounts for the form of circular coral reefs and lagoon islands, and which will be explained in the last chapter of the third book, will satisfy the reader that there are spaces on the globe, several thousand miles in circumference, throughout which the downward movement has predominated for ages, and yet the land has never, in a single instance, gone down suddenly for several hundred feet at once. Yet geology demonstrates that the persistency of subterranean movements in one direction has not been perpetual throughout all past time. There have been great oscillations of level by which a surface of dry land has been submerged to a depth of several thousand feet, and then at a period long subsequent raised again and made to emerge. Nor have the regions now motionless been always at rest; and some of those which are at present the theatres of reiterated earthquakes have formerly

enjoyed a long continuance of tranquillity. But although disturbances have ceased after having long prevailed; or have recommenced after a suspension for ages, there has been no universal disruption of the earth's crust or desolation of the surface since times the most remote. The non-occurrence of such a general convulsion is proved by the perfect horizontality now retained by some of the most ancient fossiliferous strata throughout wide areas.

Inferences derived from unconformable strata.—That the subterranean forces have visited different parts of the globe at successive periods is inferred chiefly from the unconformability of strata belonging to groups of different ages. Thus, for example, on the borders of Wales and Shropshire we find the slaty beds of the ancient Silurian system curved and vertical, while the beds of the overlying Carboniferous shale and sandstone are horizontal. All are agreed, that in such a case the older set of strata had suffered great dislocation before the deposition of the newer or Carboniferous beds, and that these last have never since been convulsed by any movements of excessive violence. But the strata of the inferior group suffered only a local derangement, and rocks of the same age are by no means found every where in a curved or vertical position. In various parts of Europe, and particularly near Lake Wener, in the south of Sweden, beds of the same Silurian system maintain the most perfect horizontality, and a similar observation may be made respecting limestones and shales of the like antiquity in the great lake district of Canada and the United States. They are still as flat and horizontal as when first formed, yet since their origin not only have most of the actual mountain chains been uplifted,

but the very rocks of which those mountains are composed have been formed.

It would be easy to multiply instances of similar unconformability in formations of other ages, but a few more will suffice. The Coal-measures before alluded to as horizontal on the borders of Wales are vertical in the Mendip Hills in Somersetshire, where the overlying beds of the New Red Sandstone are horizontal. Again, in the Wolds of Yorkshire the last-mentioned sandstone supports on its curved and inclined beds the horizontal Chalk. The Chalk again is vertical on the flanks of the Pyrenees, and the tertiary strata repose unconformably upon it.

Consistency of local disturbances with general uniformity. — As almost every country supplies illustrations of the same phenomena, they who advocate the doctrine of alternate periods of disorder and repose may appeal to the facts above described, as proving that every district has been by turns convulsed by earthquakes, and then respite for ages from convulsions. But so it might with equal truth be affirmed, that every part of Europe has been visited alternately by winter and summer, although it has always been winter and always summer in some part of the planet, and neither of these seasons has ever reigned simultaneously over the entire globe. They have been always shifting about from place to place; but the vicissitudes which recur thus annually in a single spot are never allowed to interfere with the invariable uniformity of seasons throughout the whole planet.

So, in regard to subterranean movements, the theory of the perpetual uniformity of the force which they exert on the earth's crust is quite consistent with the admission of their alternate development and suspen-

sion for indefinite periods within limited geographical areas.

UNIFORMITY OF CHANGE CONSIDERED, THIRDLY, IN REFERENCE TO SEDIMENTARY DEPOSITION.

It now remains to speak of the laws governing the deposition of new strata. If we survey the surface of the globe we immediately perceive that it is divisible into areas of deposition and non-deposition, or, in other words, at any given time there are spaces which are the recipients, others which are not the recipients of sedimentary matter. No new strata, for example, are thrown down on dry land, which remains the same from year to year; whereas, in many parts of the bottom of seas and lakes, mud, sand, and pebbles are annually spread out by rivers and currents. There are also great masses of limestone growing in some seas, or in mid ocean, chiefly composed of corals and shells.

No sediment deposited on dry land.—As to the dryland, so far from being the receptacle of fresh accessions of matter, it is exposed almost every where to waste away. Forests may be as dense and lofty as those of Brazil, and may swarm with quadrupeds, birds, and insects, yet at the end of ten thousand years one layer of black mould, a few inches thick, may be the sole representative of those myriads of trees, leaves, flowers, and fruits, those innumerable bones and skeletons of birds, quadrupeds, and reptiles, which tenanted the fertile region. Should this land be at length submerged, the waves of the sea may wash away in a few hours the scanty covering of mould, and it may merely impart a darker shade of colour to the next stratum of marl, sand, or other matter newly thrown down. So also at the bottom of the ocean where no sediment is accumulating, sea-weed, zoophytes, fish, and even shells,

may multiply for ages and decompose, leaving no vestige of their form or substance behind. Their decay, in water, although more slow, is as certain and eventually as complete as in the open air. Nor can they be perpetuated for indefinite periods in a fossil state unless imbedded in some matrix which is impervious to water, or which at least does not allow a free percolation of that fluid, impregnated as it usually is with a slight quantity of carbonic or other acid. Such a free percolation may be prevented either by the mineral nature of the matrix itself, or by the superposition of an impermeable stratum; but if unimpeded, the fossil shell or bone will be dissolved and removed, particle after particle, and thus entirely effaced, unless petrifaction or the substitution of mineral for organic matter happen to take place.

That there has been land as well as sea at all former geological periods, we know from the fact, that fossil trees and terrestrial plants are imbedded in rocks of every age. Occasionally lacustrine and fluviatile shells, insects, or the bones of amphibious or land reptiles, point to the same conclusion. The existence of dry land at all periods of the past implies, as before mentioned, the partial deposition of sediment, or its limitation to certain areas, and the next point to which I shall call the reader's attention is the shifting of these areas from one region to another.

First, then, variations in the site of sedimentary deposition are brought about independently of subterranean movements. There is always a slight change from year to year, or from century to century. The sediment of the Rhone, for example, thrown into the lake of Geneva is now conveyed to a spot a mile and a half distant from that where it accumulated in the tenth century, and six miles

from the point where the delta began originally to form. We may look forward to the period when this lake will be filled up, and then the distribution of the transported matter will be suddenly altered, for the mud and sand brought down from the Alps will thenceforth, instead of being deposited near Geneva, be carried nearly 200 miles southwards, where the Rhone enters the Mediterranean.

In the deltas of large rivers, such as those of the Ganges and Indus, the mud is first carried down for many centuries through one arm, and on this being stopped up it is discharged by another, and may then enter the sea at a point 50 or 100 miles distant from its first receptacle. The direction of marine currents is also liable to be changed by various accidents, as by the heaping up of new sand banks, or the wearing away of cliffs and promontories.

But, secondly, all these causes of fluctuation in the sedimentary areas are entirely subordinate to those great upward or downward movements of land which have been already described as prevailing over large tracts of the globe. By such elevation or subsidence certain spaces are gradually submerged, or made gradually to emerge:—in the one case sedimentary deposition may be suddenly renewed after having been suspended for ages, in the other as suddenly made to cease after having continued for an indefinite period.

Causes of variation in mineral character of successive sedimentary groups.—If deposition be renewed after a long interval, the new strata will usually differ greatly from the sedimentary rocks previously formed in the same place, and especially if the older rocks have suffered derangement, which implies a change in the physical geography of the district since the previous

conveyance of sediment to the same spot. It may happen, however, that, even when the inferior group is horizontal and conformable to the upper strata, these last may still differ entirely in mineral character, because since the origin of the older formation the geography of some distant country has been altered. In that country rocks before concealed may have become exposed by denudation, volcanos may have burst out and covered the surface with scoriae and lava, or new lakes may have been formed by subsidence; and other fluctuations may have occurred by which the materials brought down from thence by rivers to the sea have acquired a distinct mineral character.

It is well known that the stream of the Mississippi is charged with sediment of a different colour from that of the Arkansas and Red Rivers, which are tinged with red mud, derived from rocks of porphyry in "the far west." The waters of the Uruguay, says Darwin, draining a granitic country, are clear and black, those of the Parana red.* The mud with which the Indus is loaded, says Burnes, is of a clayey hue, that of the Chenab, on the other hand, is reddish, that of the Sutlej more pale.† The same causes which make these several rivers, sometimes situated at no great distance the one from the other, to differ greatly in the character of their sediment, will make the waters draining the same country at different epochs, especially before and after great revolutions in physical geography, to be entirely dissimilar. It is scarcely necessary to add, that marine currents will be affected in an analogous manner in consequence of the formation of new shoals, the emergence of new islands,

* Darwin's Journal, p. 163.

† Journ. Roy. Geograph. Soc. vol. iii. p. 142.

the subsidence of others, the gradual waste of neighbouring coasts, the growth of new deltas, the increase of coral reefs, and other changes.

Why successive sedimentary groups contain distinct fossils. — If, in the next place, we assume, for reasons before stated, a continual extinction of species and introduction of others into the globe, it will then follow that the fossils of strata formed at two distant periods on the same spot will differ even more certainly than the mineral composition of the same. For rocks of the same kind have sometimes been reproduced in the same district after a long interval of time, whereas there are no facts leading to the opinion that species which have once died out have ever been reproduced. The submergence then of land must be often attended by the commencement of a new class of sedimentary deposits, characterized by a new set of fossil animals and plants, while the reconversion of the bed of the sea into land may arrest at once and for an indefinite time the formation of geological monuments. Should the land again sink strata will again be formed; but one or many entire revolutions in animal or vegetable life may have been completed in the interval.

Conditions requisite for the original completeness of a fossiliferous series. — If we infer, for reasons before explained, that fluctuations in the animate world are brought about by the slow and successive removal and creation of species, we shall be convinced that a rare combination of circumstances alone can give rise to such a series of strata as will bear testimony to a gradual passage from one state of organic life to another. To produce such strata nothing less will be requisite than the fortunate coincidence of the following conditions: first, a never-failing supply of sediment in the same

region throughout a period of vast duration ; secondly, the fitness of the deposit in every part for the permanent preservation of imbedded fossils ; and, thirdly, a gradual subsidence to prevent the sea or lake from being filled up and converted into land.

It will appear in the chapter on coral reefs (Book III. chap. xviii.) that, in certain parts of the Pacific and Indian oceans, most of these conditions, if not all, are complied with, and the constant growth of coral, keeping pace with the sinking of the bottom of the sea, seems to have gone on so slowly, for such indefinite periods, that the signs of a gradual change in organic life might probably be detected in that quarter of the globe, if we could explore its submarine geology. Instead of the growth of coralline limestone, let us suppose, in some other place, the continuous deposition of fluviatile mud and sand, such as the Ganges and Burrampooter have poured for thousands of years into the Bay of Bengal. Part of this bay, although of considerable depth, might at length be filled up before an appreciable amount of change was effected in the fish, mollusca, and other inhabitants of the sea and neighbouring land. But, if the bottom be lowered by sinking at the same rate that it is raised by fluviatile mud, the bay can never be turned into dry land. In that case one new layer of matter may be superimposed upon another for a thickness of many thousand feet, and the fossils of the inferior beds may differ greatly from those entombed in the uppermost, yet every intermediate gradation may be indicated in the passage from an older to a newer assemblage of species. Granting, however, that such an unbroken sequence of monuments may thus be elaborated in certain parts of the sea, and that the strata happen

to be all of them well adapted to preserve the included fossils from decomposition, how many accidents must still concur before these submarine formations will be laid open to our investigation. The whole deposit must first be raised several thousand feet, in order to bring into view the very foundation; and during the process of exposure the superior beds must not be entirely swept away by denudation.

In the first place, the chances are as three to one against the mere emergence of the mass above the waters, because three fourths of the globe are covered by the ocean. But if it be upheaved and made to constitute part of the dry land, it must also, before it can be available for our instruction, become part of that area already surveyed by geologists; and this area comprehends perhaps less than a tenth of the whole earth. In this small fraction of land already explored, and still very imperfectly known, we are required to find a set of strata, originally of limited extent, and probably much lessened by subsequent denudation.

Yet it is precisely because we do not encounter at every step the evidence of such gradations from one state of the organic world to another, that so many geologists embrace the doctrine of great and sudden revolutions in the history of the animate world. Not content with simply availing themselves, for the convenience of classification, of those gaps and chasms which here and there interrupt the continuity of the chronological series, as at present known, they deduce, from the frequency of these breaks in the chain of records, an irregular mode of succession in the events themselves both in the organic and inorganic world. But, besides that some links of the chain which once existed are now clearly lost and others concealed

from view, we have good reason to suspect that it was never complete originally. It may undoubtedly be said, that strata have been always forming somewhere, and therefore at every moment of past time nature has added a page to her archives; but, in reference to this subject, it should be remembered that we can never hope to compile a consecutive history by gathering together monuments which were originally detached and scattered over the globe. For as the species of organic beings contemporaneously inhabiting remote regions are distinct, the fossils of the first of several periods which may be preserved in any one country, as in America, for example, will have no connection with those of a second period found in India, and will therefore no more enable us to trace the signs of a gradual change in the living creation, than a fragment of Chinese history will fill up a blank in the political annals of Europe.

How far some of the great violations of continuity which now exist in the chronological table of fossiliferous rocks, will hereafter be removed or lessened, must at present be mere matter of conjecture. The hiatus which exists in Great Britain between the fossils of the Lias and those of the Magnesian Limestone, is supplied in Germany by the rich fauna and flora of the Muschelkalk, Keuper, and Bunter Sandstein, which we know to be of a date precisely intermediate; those three formations being interposed in Germany between others which agree perfectly in their organic remains with our Lias and Magnesian Limestone. Until lately the fossils of the Coal-measures were separated from those of the antecedent Silurian group, by a very abrupt and decided line of demarcation; but recent discoveries have brought to light in Devonshire,

Belgium, the Eifel, and Westphalia, the remains of a fauna of an intervening period. This connecting link is furnished by the fossil shells, fish, and corals of the Devonian or Old Red Sandstone group, and some species of this newly intercalated fauna are found to be common to it and the subjacent Silurian rocks, while other species belong to it in common with the Coal-measures. Whether we shall ever succeed in like manner in diminishing greatly the hiatus which still separates the Cretaceous and Eocene periods in Europe cannot now be foreseen, but we must be prepared to expect, for reasons before stated, that some such chasms will for ever continue to occur in some parts of our sedimentary series.

Concluding remarks on the consistency of the theory of gradual change, with the existence of great breaks in the series.—But to conclude this part of my subject, it is assumed, for reasons above explained, that a slow change of species is in simultaneous operation everywhere throughout the habitable surface of sea and land ; whereas the fossilization of plants and animals is confined to those areas where new strata are produced. These areas, as we have seen, are always shifting their position ; so that the fossilizing process, by means of which the commemoration of the particular state of the organic world, at any given time, is effected, may be said to move about, visiting and revisiting different tracts in succession.

To make still more clear the supposed working of this machinery, I shall compare it to a somewhat analogous case that might be imagined to occur in the history of human affairs. Let the mortality of the population of a large country represent the successive extinction of species, and the births of new individuals

the introduction of new species. While these fluctuations are gradually taking place every where, suppose commissioners to be appointed to visit each province of the country in succession, taking an exact account of the number, names, and individual peculiarities of all the inhabitants, and leaving in each district a register containing a record of this information. If, after the completion of one census, another is immediately made on the same plan, and then another, there will, at last, be a series of statistical documents in each province. When those belonging to any one province are arranged in chronological order, the contents of such as stand next to each other will differ according to the length of the intervals of time between the taking of each census. If, for example, there are sixty provinces, and all the registers are made in a single year and renewed annually, the number of births and deaths will be so small, in proportion to the whole of the inhabitants, during the interval between the compiling of two consecutive documents, that the individuals described in such documents will be nearly identical; whereas, if the survey of each of the sixty provinces occupies all the commissioners for a whole year, so that they are unable to revisit the same place until the expiration of sixty years, there will then be an almost entire discordance between the persons enumerated in two consecutive registers in the same province. There are, undoubtedly, other causes besides the mere quantity of time, which may augment or diminish the amount of discrepancy. Thus, at some periods a pestilential disease may have lessened the average duration of human life, or a variety of circumstances may have caused the births to be unusually numerous, and the population to multiply; or, a province may be

suddenly colonized by persons migrating from surrounding districts.

These exceptions may be compared to the accelerated rate of fluctuation in the fauna and flora of a particular region, in which the climate and physical geography, may be undergoing an extraordinary degree of alteration.

But I must remind the reader, that the case above proposed has no pretensions to be regarded as an exact parallel to the geological phenomena which I desire to illustrate; for the commissioners are supposed to visit the different provinces in rotation; whereas the commemorating processes by which organic remains become fossilized, although they are always shifting from one area to another, are yet very irregular in their movements. They may abandon and revisit many spaces again and again, before they once approach another district; and, besides this source of irregularity, it may often happen that, while the depositing process is suspended, denudation may take place, which may be compared to the occasional destruction by fire or other causes of some of the statistical documents before mentioned. It is evident that, where such accidents occur, the want of continuity in the series may become indefinitely great, and that the monuments which follow next in succession will by no means be equidistant from each other in point of time.

If this train of reasoning be admitted, the occasional distinctness of the fossil remains, in formations immediately in contact, would be a necessary consequence of the existing laws of sedimentary deposition and subterranean movement, accompanied by a constant mortality and renovation of species.

As all the conclusions above insisted on are directly

opposed to opinions still popular, I shall add another comparison, in the hope of preventing any possible misapprehension of the argument. Suppose we had discovered two buried cities at the foot of Vesuvius, immediately superimposed upon each other, with a great mass of tuff and lava intervening, just as Portici and Resina, if now covered with ashes, would overlie Herculaneum. An antiquary might possibly be entitled to infer, from the inscriptions on public edifices, that the inhabitants of the inferior and older city were Greeks, and those of the modern town Italians. But he would reason very hastily if he also concluded from these data, that there had been a sudden change from the Greek to the Italian language in Campania. But if he afterwards found *three* buried cities, one above the other, the intermediate one being Roman, while, as in the former example, the lowest was Greek and the uppermost Italian, he would then perceive the fallacy of his former opinion, and would begin to suspect that the catastrophes, by which the cities were inhumed, might have no relation whatever to the fluctuations in the language of the inhabitants; and that, as the Roman tongue had evidently intervened between the Greek and Italian, so many other dialects may have been spoken in succession, and the passage from the Greek to the Italian may have been very gradual; some terms growing obsolete, while others were introduced from time to time.

If this antiquary could have shown that the volcanic paroxysms of Vesuvius were so governed as that cities should be buried one above the other, just as often as any variation occurred in the language of the inhabitants, then, indeed, the abrupt passage from a Greek to a Roman, and from a Roman to an Italian city,

would afford proof of fluctuations no less sudden in the language of the people.

So, in Geology, if we could assume that it is part of the plan of nature to preserve, in every region of the globe, an unbroken series of monuments to commemorate the vicissitudes of the organic creation, we might infer the sudden extirpation of species, and the simultaneous introduction of others, as often as two formations in contact are found to include dissimilar organic fossils. But we must shut our eyes to the whole economy of the existing causes, aqueous, igneous, and organic, if we fail to perceive *that such is not the plan of Nature.*

CHAPTER XII.

SUPPOSED SUDDEN UPHEAVAL AND PARALLELISM OF CONTEMPORANEOUS MOUNTAIN CHAINS.

Statement of the theory of the sudden upheaval of parallel mountain chains — Objections to the proof of the suddenness of the upheaval, and the contemporaneousness of parallel chains — As large tracts of land are rising or sinking slowly, so narrow zones of land may be pushed up to great heights gradually — Trains of active volcanos not parallel.

THE doctrine of the suddenness and universality of the revolutions which the physical geography of the globe has undergone, at successive periods of the past, has been thought by some to acquire additional strength from a theory respecting the origin of mountain chains, recently put forth by a distinguished geologist, M. Elie de Beaumont. In an essay on this subject he has attempted to establish two points; first, that a variety of independent chains of mountains have been thrown up suddenly at particular periods; and, secondly, that all the contemporaneous chains thus thrown up preserve a parallelism the one to the other, even in the most distant regions.

These opinions, and others by which they are accompanied, are so adverse to the views advocated in the foregoing chapter, and to the method of theorizing in geology which I have recommended, that I am desirous of explaining the grounds of my dissent,

a course which I feel myself the more called upon to adopt, as the generalizations alluded to are those of a skilful writer, and an original observer of great talent and experience. I shall begin, therefore, by giving a brief summary of the principal propositions laid down in the work above referred to.

1st. M. de Beaumont supposes, "that in the history of the earth there have been long periods of comparative repose, during which the deposition of sedimentary matter has gone on in regular continuity; and there have also been short periods of paroxysmal violence, during which that continuity was broken."

"2dly. At each of these periods of violence or 'revolution' in the state of the earth's surface a great number of mountain-chains have been formed suddenly.

"3dly. All the chains thrown up by a particular revolution have one uniform direction, being parallel to each other within a few degrees of the compass, even when situated in remote regions; but the chains thrown up at different periods have, for the most part, different directions.

"4thly. Each 'revolution,' or, as it is sometimes termed, 'frightful convulsion,' has fallen in with the date of another geological phenomenon; namely, 'the passage from one independent sedimentary formation to another,' characterized by a considerable difference in 'organic types.'

"5thly. There has been a recurrence of these paroxysmal movements from the remotest geological periods; and they may still be reproduced, and the repose in which we live may hereafter be broken by the sudden upthrow of another system of parallel chains of mountains.

"6thly. We may presume that one of these revolutions has occurred within the historical era, when the Andes were upheaved to their present height; for that chain is the best defined and least obliterated feature observable in the present exterior configuration of the globe, and was probably the last elevated.

"7thly. The instantaneous upheaving from the ocean of great mountain masses must cause a violent agitation in the waters; and the rise of the Andes may, perhaps, have produced that transient deluge which is noticed among the traditions of so many nations.

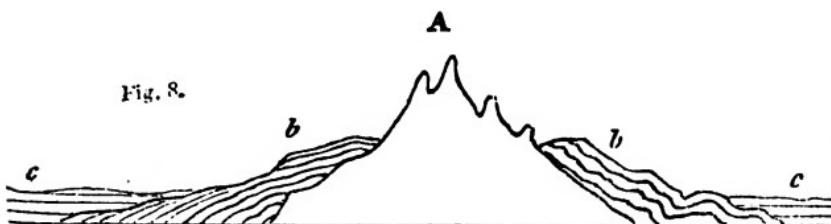
"Lastly. The successive revolutions above mentioned cannot be referred to ordinary volcanic forces, but may depend on the secular refrigeration of the heated interior of our planet." *

The greater number of the topics enumerated in the above summary have been discussed by anticipation in the last chapter, and I shall now confine myself to what I conceive to be the insufficiency of the proofs adduced in favour of the suddenness of the upthrow, and the contemporaneousness of the origin of the parallel chains referred to. At the same time I may remark, that the great body of facts collected together by M. de Beaumont will always form an invaluable addition to our knowledge, tending as they do to confirm the doctrine that different mountain-chains have been formed in succession, and indicating, at the same

* Ann. des Sci. Nat., Septembre, Novembre, et Décembre, 1829. Revue Française, No. 15. May, 1830. The last edition by M. de B. is in De la Beche's Manual, 3d edit.; and D'Aubuisson, *Traité de Géognosie*, tom. iii. p. 282. 1835; also referred to by De Beaumont, *Instruct. pour l'explor. de l'Algérie*, 1838.

time, that there are certain determinate lines of direction or strike in the strata of various countries.

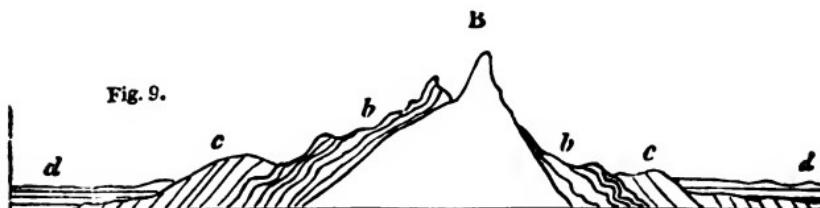
The following may serve as an analysis of the evidence on which the new theory depends. We observe, says M. de Beaumont, "when we attentively examine nearly all mountain chains, that the most recent rocks extend horizontally up to the foot of such chains, as we should expect would be the case if they were deposited in seas or lakes, of which these mountains have partly formed the shores; whilst the other sedimentary beds, tilted up, and more or less contorted, on the flanks of the mountains, rise in certain points even to their highest crests."* There are, therefore, in and adjacent to each chain, two classes of sedimentary rocks, the ancient or inclined beds, and the newer or horizontal. It is evident that the first appearance of the chain itself was an event "intermediate between the period when the beds now upraised were deposited and that when the strata were produced horizontally at its feet."



Thus the chain A assumed its present position after the deposition of the strata *b*, which have undergone great movements, and before the deposition of the group *c*, in which the strata have not suffered derangement.

* Phil. Mag. and Annals, No. 58., New Series, p. 242.

If we then discover another chain B, in which we find not only the formation *b*, but the group *c* also,



disturbed and thrown on its edges, we may infer that the latter chain is of subsequent date to A; for B must have been elevated *after* the deposition of *c*, and before that of the group *d*; whereas A had originated *before* the strata *c* were formed.

It is then argued, that in order to ascertain whether other mountain ranges are of contemporaneous date with A and B, or are referable to *distinct* periods, we have only to inquire whether the inclined and undisturbed sets of strata in each range correspond with or differ from those in the types A and B.

Now all this reasoning is perfectly correct, so long as the periods of the deposition of the particular local groups of strata *b* and *c* are not confounded with the periods during which the animals and plants found fossil in *b* and *c* may have flourished, and provided also that due latitude is given to the term contemporaneous; for this term must be understood to allude, not to a moment of time, but to the interval, whether brief or protracted, which elapsed between two events, namely, between the accumulation of the inclined and that of the horizontal strata.

But, unfortunately, no attempt has been made in the treatise under review to avoid this manifest source of confusion, and hence the very terms of each proposition are equivocal; and the possible length of some of

the intervals is so vast, that to affirm that all the chains raised in such intervals were *contemporaneous* is an abuse of language.

In order to illustrate this argument, I shall select the Pyrenees as an example. This range of mountains, says M. de Beaumont, rose suddenly (*à un seul jet* *) to its present elevation at a certain epoch in the earth's history, namely, between the deposition of the Chalk and that of the tertiary formations; for the Chalk is seen in vertical, curved, and distorted beds on the flanks of the chain, as the beds *b*, Fig. 8., while the tertiary formations rest upon them in horizontal strata at its base, as *c*, ibid.

The proof then of the extreme suddenness of the convulsion is the supposed shortness of the time which intervened between the formation of the chalk, and the origin of certain tertiary strata.† Yet even if the interval were reducible within these limits, it might comprise an indefinite lapse of time. In strictness of reasoning, however, we cannot permit the author to exclude the whole either of the Cretaceous or tertiary periods, from the possible duration of the interval during all or any part of which the elevation may have taken place. For, in the first place, it cannot be assumed, that the movement of upheaval took place after the close of the Cretaceous period; we can merely say, that it occurred after the deposition of certain strata of that period; secondly, although it be true that the event happened before the formation of certain

* In the last edition of M. de B.'s system (see note above, p. 306.), he only speaks of the convulsion which raised the Pyrenees, as "one of the most violent which the land of Europe ever experienced."

† Phil. Mag. and Annals, No. 53., New Series, p. 243.

tertiary strata now at the base of the Pyrenees, it by no means follows that it preceded the whole tertiary epoch.

The upheaving of the Pyrenees, therefore, may have been going on before the animals of the Chalk period ceased to exist, or when the Maestricht beds were in progress, or during the indefinite ages which may have elapsed between the extinction of the Maestricht animals and the introduction of the Eocene tribes, or during the Eocene epoch, or the rise may have been going on throughout one, or several, or all of these periods.

It would be a purely gratuitous assumption to say that the inclined cretaceous strata (*b*, Fig. 8.) on the flanks of the Pyrenees were the very last which were deposited during the Cretaceous period, or that, as soon as they were upheaved, all or nearly all the species of animals and plants now found fossil in them were suddenly exterminated; yet, unless this can be affirmed, we cannot say that the Pyrenees were not upheaved during the Cretaceous period. Consequently, another range of mountains, at the base of which cretaceous rocks may lie in horizontal stratification, may have been elevated, like the chain A, Fig. 8., during some part of the same great period.

There are mountains in Sicily two or three thousand feet high, the tops of which are composed of limestone, in which nearly all the fossil shells and zoophytes agree specifically with those now inhabiting the Mediterranean. Here, as in many other countries, the deposits now in progress in the sea must inclose shells and other fossils specifically identical with those of the rocks constituting the contiguous land. So there are islands in the Pacific, where a mass of dead coral has emerged to a considerable altitude, while

other portions of the mass remain beneath the sea, still increasing by the growth of living zoophytes and shells. The chalk of the Pyrenees, therefore, may at a remote period have been raised to an elevation of several thousand feet, while the species found fossil in the same chalk still continued to be represented in the fauna of the neighbouring ocean. In a word, we cannot assume that the origin of a new range of mountains caused the Cretaceous period to cease, and served as the prelude to a new order of things in the animate creation.

To illustrate the grave objections above advanced, against the theory considered in the present chapter, let us suppose, that in some country three styles of architecture had prevailed in succession, each for a period of one thousand years; first the Greek, then the Roman, and then the Gothic; and that a tremendous earthquake was known to have occurred in the same district during one of the three periods—a convulsion of such violence as to have levelled to the ground all the buildings then standing. If an antiquary, desirous of discovering the date of the catastrophe, should first arrive at a city where several Greek temples were lying in ruins and half engulfed in the earth, while many Gothic edifices were standing uninjured, could he determine on these data the era of the shock? Could he even exclude any one of the three periods, and decide that it must have happened during one of the other two? Certainly not. He could merely affirm that it happened at some period after the introduction of the Greek style, and before the Gothic had fallen into disuse. Should he pretend to define the date of the convulsion with greater precision, and decide that the earthquake must have

occurred after the Greek and before the Gothic period, that is to say, when the Roman style was in use, the fallacy in his reasoning would be too palpable to escape detection for a moment.

Yet such is the nature of the erroneous induction which I am now exposing. For as, in the example above proposed, the erection of a particular edifice is perfectly distinct from the period of architecture in which it may have been raised, so is the deposition of chalk, or any other set of strata, from the geological epochs characterized by certain fossils to which they may belong.

It is almost superfluous to enter into any farther analysis of the theory of parallelism, because the whole force of the argument depends on the accuracy of the data by which the contemporaneous or non-contemporaneous date of the elevation of two independent chains can be demonstrated. In every case, this evidence, as stated by M. de Beaumont, is equivocal, because he has not included in the possible interval of time between the deposition of the deranged and the horizontal formations part of the periods to which each of those classes of formations are referable. All the geological facts, therefore, adduced by the author may be true, and yet the conclusion that certain chains were or were not simultaneously upraised is by no means a legitimate consequence.

At the same time, it should be observed, that geologists are by no means agreed in regard to the parallelism of the *strike* of all the chains said to be contemporaneous, and many of those referred to in Africa, Asia, India, and South America, are too slightly known, even geographically, to afford data for secure generalization.

Slow upheaval and subsidence of broad areas. — We have already seen that recent observations have unexpectedly disclosed to us the wonderful fact, that large areas, some of them several thousand miles in circumference, comprehending among others Scandinavia, the west coast of South America, and certain archipelagos in the Pacific, are slowly and insensibly rising ; while other regions, such as Greenland, and parts of the Pacific and Indian oceans, in which atolls or circular coral islands abound, are as gradually sinking. That all the existing continents and submarine abysses may have originated in movements of this kind, continued throughout incalculable periods of time, is undeniable, and the denudation which the dry land appears every where to have suffered favours the idea that it was raised from the deep by a succession of upward movements, prolonged throughout indefinite periods. For the action of waves and currents on land slowly emerging from the deep affords the only power by which we can conceive so many deep valleys and wide spaces to have been denuded as those which are unquestionably the effects of running water ; and one of the soundest objections to the theory of the sudden upthrow of continental masses is, that it deprives us of that great power, so necessary to account for the external configuration of every island and continent.

The uplifting of a narrow zone of land may be equally slow. — But perhaps it may be said that there is no analogy between the slow upheaval of broad plains or table lands, and the manner in which we must presume all mountain chains, with their inclined strata, to have originated. We find, however, certain lofty ranges, like the Andes, in which volcanic action and earthquakes are developed with considerable energy along

determinate lines; and the western part of South America may have risen, century after century, at the rate of several feet, while the Pampas on the east have been raised only a few inches in the same time. In crossing from the Atlantic to the Pacific, in a line passing through Mendoza, we traverse a plain 800 miles broad, the eastern part of which has emerged from beneath the sea at a very modern period. The slope from the Atlantic is at first very gentle, then greater, until the traveller finds, on reaching Mendoza, that he has gained, almost insensibly, a height of 4000 feet. The mountainous district then begins suddenly, and its breadth from Mendoza to the shores of the Pacific is 120 miles, the average height of the principal chain being from 15,000 to 16,000 feet, without including some prominent peaks, which ascend much higher. Now all we require, to explain the origin of the principal inequalities of level here described, is to imagine a zone of more violent movement to the west of Mendoza, and to the east of that place an upheaving force which died away gradually as it approached the Atlantic. In short, we are only called upon to conceive, that the region of the Andes was pushed up four feet in the same period in which the Pampas near Mendoza rose one foot, and the plains near the shores of the Atlantic one inch. In Europe, we have learnt that the land at the North Cape ascends about five feet in a century, while farther to the south the movements diminish in quantity first to a foot, and then, at Stockholm, to three inches in a century, while at points still farther south there is no movement.

Lines of active volcanos not parallel.—I shall now conclude by remarking that, if earthquakes and vol-

canos are both of them the effects of one and the same cause, it is highly probable that earthquakes are developed for ages along narrow zones. And as the trains of active volcanos, although linear, have not all of them one uniform direction, but are sometimes at right angles the one to the other, so is it probable that we shall find in the lines of subterranean convolution, whether of upheaval or subsidence, a wide deviation from parallelism.

CHAPTER XIII.

DIFFERENCE IN TEXTURE OF THE OLDER AND NEWER ROCKS.

Consolidation of fossiliferous strata — Some deposits originally solid — Transition and slaty texture — Crystalline character of Plutonic and Metamorphic rocks — Theory of their origin — Essentially subterranean — No proofs that they were produced more abundantly at remote periods — Concluding remarks on the identity of the ancient and present system of terrestrial changes.

ANOTHER argument in favour of the dissimilarity of the causes operating at remote and recent eras has been derived by many geologists from the more compact, stony, and crystalline texture of the older as compared to the newer rocks.

Consolidation of strata. — This subject may be considered, first, in reference to the fossiliferous strata ; and, secondly, in reference to those crystalline and stratified rocks which contain no organic remains, such as gneiss and mica-schist. There can be no doubt that the former of these classes, or the fossiliferous, are generally more compact and stony in proportion as they are more ancient. It is also certain that a great part of them were originally in a soft and incoherent state, and that they have been since consolidated. Thus we find occasionally loose shingle and sand agglutinated firmly together by a ferruginous or siliceous cement, or that lime in solution has been introduced, so as to bind together materials previously incoherent.

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The constituents of some beds have probably set and become hard when they emerged from beneath the water, as the marl of Lake Superior, which incloses fresh-water shells, and which is no sooner exposed to the air than it becomes solid, so as only to be broken by a smart blow of the hammer. Organic remains have sometimes suffered a singular transformation, as, for example, where shells, corals, and wood are silicified, their calcareous or ligneous matter having been replaced by nearly pure silica.

But, on the other hand, we observe in certain formations now in progress, particularly in coral reefs, and in deposits from the waters of mineral springs, both calcareous and siliceous, that the texture of rocks may sometimes be stony from the first. This circumstance may account for exceptions to the general rule, not unfrequently met with, where solid strata are superimposed on others of a plastic and incoherent nature, as in the neighbourhood of Paris, where the tertiary formations, consisting often of compact limestone and siliceous grit, are more stony than the subjacent chalk.

It will readily be understood, that the various solidifying causes, including those above enumerated, together with the pressure of incumbent rocks and the influence of subterranean heat, must all of them require time in order to exert their full power. If in the course of ages they modify the aspect and internal structure of stratified deposits, they will give rise to a general distinctness of character in the older as contrasted with the newer formations. But this distinctness will not be the consequence of any original diversity; they will be unlike, just as the wood in the older trees of a forest usually differs in texture and hardness from that of younger individuals of the same species.

Transition texture.—In the original classification of Werner, the highly crystalline rocks, such as granite and gneiss, which contain no organic remains, were called primary, and the fossiliferous strata secondary, while to another class of an age intermediate between the primary and secondary he gave the name of transition. They were termed transition because they partook in some degree in their mineral composition of the nature of the most crystalline rocks, such as gneiss and mica-schist, while they resembled the fossiliferous series in containing occasionally organic remains, and exhibiting evident signs of a mechanical origin. It was at first imagined, that the rocks having this intermediate texture had been all deposited subsequently to the series called primary, and before all the more earthy and fossiliferous formations. But when the relative position and organic remains of these transition rocks were better understood, it was perceived that they did not all belong to one period. On the contrary, the same mineral characters were found in strata of very different ages, and some formations occurring in the Alps, which several of the ablest scholars of Werner had determined to be transition, were ultimately ascertained, by means of their fossil contents and position, to be members of the Cretaceous period. These strata had, in fact, acquired the *transition* texture from the influence of causes which, since their deposition, had modified their internal arrangement.

Texture and origin of Plutonic and metamorphic rocks.—Among the most singular of the changes superinduced on rocks we have occasionally to include the slaty texture, the divisional planes of which sometimes intersect the true planes of stratification, and even pass directly through imbedded fossils. If, then, the crystalline, the

slaty, and other modes of arrangement, once deemed characteristic of certain periods in the history of the earth, have in reality been assumed by fossiliferous rocks of different ages and at different times, we are prepared to inquire whether the same may not be true of the most highly crystalline state, such as that of gneiss, mica-schist, and statuary marble. That the peculiar characteristics of such rocks are really due to a variety of modifying causes has long been suspected by many geologists, and the doctrine has gained ground of late, although a considerable difference of opinion still prevails. According to the original Neptunian theory, all the crystalline formations were precipitated from a universal menstruum or chaotic fluid antecedently to the creation of animals and plants, the unstratified granite having been first thrown down so as to serve as a floor or foundation on which gneiss and other stratified rocks might repose. Afterwards, when the igneous origin of granite was no longer disputed, many conceived that a thermal ocean enveloped the globe, at a time when the first-formed crust of granite was cooling, but when it still retained much of its heat. The hot waters of this ocean held in solution the ingredients of gneiss, mica-schist, hornblende-schist, clay-slate, and marble, which rocks were precipitated, one after the other, in a crystalline form. No fossils could be inclosed in them, the high temperature of the fluid, and the quantity of mineral matter which it held in solution, rendering it unfit for the support of organic beings.

It would be inconsistent with the plan of this work to enter here into a detailed account of what I have elsewhere termed the *metamorphic theory**; but I may

* See Elements of Geology.

state that it is now demonstrable in some countries that fossiliferous formations, some of them of the age of the Silurian strata, as near Christiania in Norway, others belonging to the Oolitic period, as around Carrara in Italy, have been converted partially into gneiss, mica-schist, and statuary marble. The transmutation has been effected apparently by the influence of subterranean heat, acting under great pressure, or by chemical and electrical causes operating in a manner not yet understood, and which have been termed *Plutonic* action, as expressing in one word all the modifying causes which may be brought into play at great depths, and under conditions never exemplified at the surface. To this Plutonic action the fusion of granite itself in the bowels of the earth, as well as the superinducement of the metamorphic texture into sedimentary strata, must be attributed; and in accordance with these views the age of each metamorphic formation may be said to be twofold, for we have first to consider the period when it originated, as an aqueous deposit, in the form of mud, sand, marl, or limestone; secondly, the date at which it acquired a crystalline texture. The same strata, therefore, may, according to this view, be very ancient in reference to the time of their deposition, and very modern in regard to the period of their assuming the metamorphic character.

No proofs that these crystalline rocks were produced more abundantly at remote periods. — Several modern writers, without denying the truth of the Plutonic or metamorphic theory, still contend that the crystalline and non-fossiliferous formations, whether stratified or unstratified, such as gneiss and granite, are essentially ancient as a class of rocks. They were generated, say they, most abundantly in a primeval state of the

globe, since which time the quantity produced has been always on the decrease, until it became very inconsiderable in the Oolitic and Cretaceous periods, and quite evanescent before the commencement of the tertiary epoch.

Now the justness of these views depends almost entirely on the question whether granite, gneiss, and other rocks of the same order, ever originated at the surface, or whether, according to the opinions above adopted, they are essentially subterranean in their origin, and therefore entitled to the appellation of *hypogene*. If they were formed superficially in their present state, and as copiously in the modern as in the more ancient periods, we ought to see a greater abundance of tertiary and secondary than of primary granite and gneiss; but if we adopt the hypogene theory before explained, their rapid diminution in volume among the visible rocks in the earth's crust in proportion as we investigate the formations of newer date is quite intelligible. If a melted mass of matter be now cooling very slowly at the depth of several miles beneath the crater of an active volcano, it must remain invisible until great revolutions in the earth's crust have been brought about. So also if stratified rocks have been subjected to Plutonic action, and after having been baked or reduced to semi-fusion, are now cooling and crystallizing far under ground, it will probably require the lapse of many periods before they will be forced up to the surface and exposed to view, even at a single point. To effect this purpose there may be need of as great a development of subterranean movement as that which in the Alps, Andes, and Himalaya has raised marine strata containing ammonites to the height of 8000, 14,000, and 16,000 feet.

By parity of reasoning we can hardly expect that any hypogene rocks of the tertiary periods will have been brought within the reach of human observation, seeing that the emergence of such rocks must always be so long posterior to the date of their origin, and still less can formations of this class become generally visible until so much time has elapsed as to confer on them a high relative antiquity. Extensive denudation must also combine with upheaval before they can be displayed at the surface throughout wide areas.

All geologists who reflect on subterranean movements now going on, and the eruptions of active volcanos, are convinced that great changes are now continually in progress in the interior of the earth's crust far out of sight. They must be conscious, therefore, that the inaccessibility of the regions in which these alterations are taking place, compels them to remain in ignorance of a great part of the working of existing causes, so that they can only form vague conjectures in regard to the nature of the products which volcanic heat may elaborate under great pressure.

But when they find in mountain chains of high antiquity that what was once the interior of the earth's crust has since been forced outwards and exposed to view, they will naturally expect, in the examination of those mountainous regions, to have an opportunity of gratifying their curiosity by obtaining a sight not only of the superficial strata of remote eras, but also of the contemporaneous nether-formed rocks. Having recognized therefore in such mountain chains some ancient rocks of aqueous and volcanic origin, corresponding in character to superficial formations of modern date, they will regard any other class of ancient rocks, such as

granite and gneiss, as the *residual phenomena* of which they are in search. These latter rocks will not answer the expectations previously formed of their probable nature and texture, unless they wear a foreign and mysterious aspect, and have in some places been fused or altered by subterranean heat; in a word, unless they differ wholly from the fossiliferous strata deposited at the surface, or from the lava and scoriae thrown out by volcanos in the open air. It is the total distinctness, therefore, of crystalline formations, such as granite, hornblende-schist, and the rest, from every substance of which the origin is familiar to us, that constitutes their claim to be regarded as the effects of causes now in action in the subterranean regions. They belong not to an order of things which have passed away; they are not the monuments of a primeval period, bearing inscribed upon them in obsolete characters the words and phrases of a dead language; but they teach us that part of the living language of nature which we cannot learn by our daily intercourse with what passes on the habitable surface.

Concluding remarks on the identity of the ancient and present system of terrestrial changes. — I shall now conclude the discussion of a question with which we have been occupied since the beginning of the fifth chapter; namely, whether there has been any interruption, from the remotest periods, of one uniform system of change in the animate and inanimate world. We were induced to enter into that inquiry by reflecting how much the progress of opinion in Geology had been influenced by the assumption that the analogy was slight in kind, and still more slight in degree, between the causes which produced the former revolu-

tions of the globe, and those now in every day operation. It appeared clear that the earlier geologists had not only a scanty acquaintance with existing changes, but were singularly unconscious of their ignorance. With the presumption naturally inspired by this unconsciousness, they had no hesitation in deciding at once that time could never enable the existing powers of nature to work out changes of great magnitude, still less such important revolutions as those which are brought to light by Geology. They, therefore, felt themselves at liberty to indulge their imaginations in guessing at what *might be*, rather than in inquiring *what is*; in other words, they employed themselves in conjecturing what might have been the course of nature at a remote period, rather than in the investigation of what was the course of nature in their own times.

It appeared to them more philosophical to speculate on the possibilities of the past, than patiently to explore the realities of the present; and having invented theories under the influence of such maxims, they were consistently unwilling to test their validity by the criterion of their accordance with the ordinary operations of nature. On the contrary, the claims of each new hypothesis to credibility appeared enhanced by the great contrast, in kind or intensity, of the causes referred to and those now in operation.

Never was there a dogma more calculated to foster indolence, and to blunt the keen edge of curiosity, than this assumption of the discordance between the ancient and existing causes of change. It produced a state of mind unfavourable in the highest degree to the candid reception of the evidence of those minute but incessant alterations which every part of the earth's

surface is undergoing, and by which the condition of its living inhabitants is continually made to vary. The student, instead of being encouraged with the hope of interpreting the enigmas presented to him in the earth's structure,—instead of being prompted to undertake laborious inquiries into the natural history of the organic world, and the complicated effects of the igneous and aqueous causes now in operation, was taught to despond from the first. Geology, it was affirmed, could never rise to the rank of an exact science,—the greater number of phenomena must for ever remain inexplicable, or only be partially elucidated by ingenious conjectures. Even the mystery which invested the subject was said to constitute one of its principal charms, affording, as it did, full scope to the fancy to indulge in a boundless field of speculation.

The course directly opposed to this method of philosophizing consists in an earnest and patient inquiry how far geological appearances are reconcileable with the effect of changes now in progress, or which may be in progress in regions inaccessible to us, and of which the reality is attested by volcanos and subterranean movements. It also endeavours to estimate the aggregate result of ordinary operations multiplied by time, and cherishes a sanguine hope that the resources to be derived from observation and experiment, or from the study of nature such as she now is, are very far from being exhausted. For this reason all theories are rejected which involve the assumption of sudden and violent catastrophes and revolutions of the whole earth, and its inhabitants,—theories which are restrained by no reference to existing analogies, and in which a de-

sire is manifested to cut, rather than patiently to untie, the Gordian knot.

We have now, at least, the advantage of knowing, from experience, that an opposite method has always put geologists on the road that leads to truth,—suggesting views which, although imperfect at first, have been found capable of improvement, until at last adopted by universal consent; while the method, of speculating on a former distinct state of things and causes, has led invariably to a multitude of contradictory systems, which have been overthrown one after the other,—have been found incapable of modification,—and which have often required to be precisely reversed.

The remainder of this work will be devoted to an investigation of the changes now going on in the crust of the earth and its inhabitants. The importance which the student will attach to such researches will mainly depend in the degree of confidence which he feels in the principles above expounded. If he firmly believes in the resemblance or identity of the ancient and present system of terrestrial changes, he will regard every fact collected respecting the causes in diurnal action as affording him a key to the interpretation of some mystery in the past. Events which have occurred at the most distant periods in the animate and inanimate world will be acknowledged to throw light on each other, and the deficiency of our information respecting some of the most obscure parts of the present creation will be removed. For as, by studying the external configuration of the existing land and its inhabitants, we may restore in imagination the appearance of the ancient continents which have passed away, so may we obtain from the deposits of ancient seas and lakes an

insight into the nature of the subaqueous processes now in operation, and of many forms of organic life, which, though now existing, are veiled from sight. Rocks, also, produced by subterranean fire in former ages, at great depths in the bowels of the earth, present us, when upraised by gradual movements, and exposed to the light of heaven, with an image of those changes which the deep-seated volcano may now occasion in the nether regions. Thus, although we are mere sojourners on the surface of the planet, chained to a mere point in space, enduring but for a moment of time, the human mind is not only enabled to number worlds beyond the unassisted ken of mortal eye, but to trace the events of indefinite ages before the creation of our race, and is not even withheld from penetrating into the dark secrets of the ocean, or the interior of the solid globe; free, like the spirit which the poet described as animating the universe,

— ire per omnes

Terrasque, tractusque maris, cœlumque profundum.

BOOK II.

CHANGES OF THE INORGANIC WORLD.

AQUEOUS CAUSES.

CHAPTER I.

Division of the subject into changes of the organic and inorganic world — Inorganic causes of change divided into aqueous and igneous — Aqueous causes first considered — Destroying and transporting power of running water — Sinuosities of rivers — Two streams when united do not occupy a bed of double surface — Heavy matter removed by torrents and floods — Recent inundations in Scotland — Erosion of chasms through hard rocks — Excavations in the lavas of Etna by Sicilian rivers — Gorge of the Simeto — Gradual recession of the cataracts of Niagara.

Division of the subject. — GEOLOGY was defined to be the science which investigates the former changes that have taken place in the organic, as well as in the inorganic kingdoms of nature. As vicissitudes in the inorganic world are most apparent, and as on them all fluctuations in the animate creation must in a great measure depend, they may claim our first consideration. The great agents of change in the organic world may be divided into two principal classes, the aqueous and the igneous. To the aqueous belong Rivers, Torrents, Springs, Currents, and Tides; to the igneous, Volcanos and Earthquakes. Both these classes are

instruments of decay as well as of reproduction ; but they may also be regarded as antagonist forces. For the aqueous agents are incessantly labouring to reduce the inequalities of the earth's surface to a level ; while the igneous are equally active in restoring the unevenness of the external crust, partly by heaping up new matter in certain localities, and partly by depressing one portion, and forcing out another, of the earth's envelope.

It is difficult, in a scientific arrangement, to give an accurate view of the combined effects of so many forces in simultaneous operation ; because, when we consider them separately, we cannot easily estimate either the extent of their efficacy, or the kind of results which they produce. We are in danger, therefore, when we attempt to examine the influence exerted singly by each, of overlooking the modifications which they produce on one another ; and these are so complicated, that sometimes the igneous and aqueous forces co-operate to produce a joint effect, to which neither of them unaided by the other could give rise, —as when repeated earthquakes unite with running water to widen a valley ; or when a thermal spring rises up from a great depth, and conveys the mineral ingredients with which it is impregnated from the interior of the earth to the surface. Sometimes the organic combine with the inorganic causes ; as when a reef, composed of shells and corals, protects one line of coast from the destroying power of tides or currents, and turns them against some other point ; or when drift timber, floated into a lake, fills a hollow to which the stream would not have had sufficient velocity to convey earthy sediment.

It is necessary, however, to divide our observations

on these various causes, and to classify them systematically, endeavouring as much as possible to keep in view that the effects in nature are mixed, and not simple, as they may appear in an artificial arrangement.

In treating, in the first place, of the aqueous causes, we may consider them under two divisions: first, those which are connected with the circulation of water from the land to the sea, under which are included all the phenomena of rivers and springs; secondly, those which arise from the movements of water in lakes, seas, and the ocean, wherein are comprised the phenomena of tides and currents. In turning our attention to the former division, we find that the effects of rivers may be subdivided into those of a destroying and those of a renovating nature; in the destroying are included the erosion of rocks, and the transportation of matter to lower levels; in the renovating class, the formation of deltas by the influx of sediment, and the shallowing of seas.

Action of running water.—I shall begin, then, by describing the destroying and transporting power of running water, as exhibited by torrents and rivers. It is well known that the lands elevated above the sea attract, in proportion to their volume and density, a larger quantity of that aqueous vapour which the heated atmosphere continually absorbs from the surface of lakes and the ocean. By these means, the higher regions become perpetual reservoirs of water, which descend and irrigate the lower valleys and plains. In consequence of this provision, almost all the water is first carried to the highest regions, and is then made to descend by steep declivities towards the sea; so that it acquires superior velocity, and removes a greater quantity of soil, than it would do if the rain

had been distributed over the plains and mountains equally in proportion to their relative areas. Almost all the water is also made by these means to pass over the greatest distances which each region affords, before it can regain the sea. The rocks also, in the higher regions, are particularly exposed to atmospheric influences, to frost, rain, and vapour, and to great annual alternations of cold and heat, of moisture and desiccation.

Among the most powerful agents of decay may be mentioned that property of water which causes it to expand during congelation ; its increase of bulk when converted into ice amounting to no less than one twentieth of the whole volume, so that when water has penetrated into the crevices of the most solid rocks, it rends them open on freezing with mechanical force.* For this reason, although in cold climates the comparative quantity of rain which falls is very inferior, and although it descends more gradually than in tropical regions, yet the severity of frost, and the greater inequalities of temperature, compensate in some degree for this diminished source of degradation. The solvent power of water also is very great, and acts particularly on the calcareous and alkaline elements of stone, especially when it holds carbonic acid in solution, which is abundantly supplied to almost every large river by springs, and is collected by rain from the atmosphere. The oxygen of the atmosphere is also gradually absorbed by all animal and vegetable productions, and by almost all mineral masses exposed to the open air. It gradually destroys the equilibrium of the elements of rocks, and tends to reduce into powder,

* Quart. Journ. of Sci., &c. new series, No. xiii. p. 194.

and to render fit for soils, even the hardest aggregates belonging to our globe.*

When earthy matter has once been intermixed with running water, a new mechanical power is obtained by the attrition of sand and pebbles, borne along with violence by a stream. Running water charged with foreign ingredients being thrown against a rock, excavates it by mechanical force, sapping and undermining till the superincumbent portion is at length precipitated into the stream. The obstruction causes a temporary ponding back of the water, which then sweeps down the barrier.

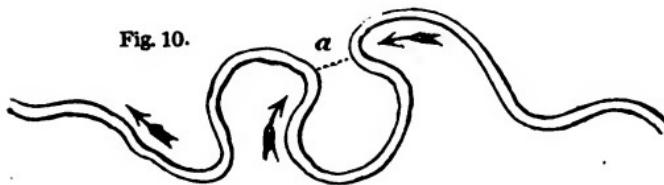
Sinuosities of rivers.—By a repetition of these landslips the ravine is widened into a small, narrow valley, in which sinuosities are caused by the deflexion of the stream first to one side and then to the other. The unequal hardness of the materials through which the channel is eroded tends partly to give new directions to the lateral force of excavation. When by these, or by accidental shifting of the alluvial matter in the channel, and numerous other causes, the current is made to cross its general line of descent, it eats out a curve in the opposite bank, or in the side of the hills bounding the valley, from which curve it is turned back again at an equal angle, so that it recrosses the line of descent, and gradually hollows out another curve lower down in the opposite bank, till the whole sides of the valley, or river-bed, present a succession of salient and retiring angles. Among the causes of deviation from a straight course by which torrents and rivers tend in mountainous regions to widen the valleys through which they flow, may be mentioned the con-

* Sir H. Davy, *Consolations in Travel*, p. 271,

fluence of lateral torrents, swollen irregularly at different seasons by partial storms, and discharging at different times unequal quantities of sand, mud, and pebbles, into the main channel.

When the tortuous flexures of a river are extremely great, the aberration from the direct line of descent is often restored by the river cutting through the isthmus which separates two neighbouring curves. Thus, in the annexed diagram, the extreme sinuosity of the

Fig. 10.



river has caused it to return for a brief space in a contrary direction to its main course, so that a peninsula is formed, and the isthmus (at *a*) is consumed on both sides by currents flowing in opposite directions. In this case an island is soon formed,—on either side of which a portion of the stream usually remains.

Transporting power of water.—In regard to the transporting power of water, we may often be surprised at the facility with which streams of a small size, and descending a slight declivity, bear along coarse sand and gravel; for we usually estimate the weight of rocks in air, and do not reflect on their comparative buoyancy when submerged in a denser fluid. The specific gravity of many rocks is not more than twice that of water, and very rarely more than thrice, so that almost all the fragments propelled by a stream have lost a third, and many of them half, of what we usually term their weight.

It has been proved by experiment, in contradiction to the theories of the earlier writers on hydrostatics, to be a universal law, regulating the motion of running water, that the velocity at the bottom of the stream is every where less than in any part above it, and is greatest at the surface. Also, that the superficial particles in the middle of the stream move swifter than those at the sides. This retardation of the lowest and lateral currents is produced by friction; and when the velocity is sufficiently great, the soil composing the sides and bottom gives way. A velocity of three inches per second at the bottom is ascertained to be sufficient to tear up fine clay,—six inches per second, fine sand,—twelve inches per second, fine gravel,—and three feet per second, stones of the size of an egg.*

When this mechanical power of running water is considered, we are prepared for the transportation of large quantities of gravel, sand, and mud, by the torrents and rivers which descend with great velocity from mountainous regions. But a question naturally arises, how the more tranquil rivers of the valleys and plains, flowing on comparatively level ground, can remove the prodigious burden which is discharged into them by their numerous tributaries, and by what means they are enabled to convey the whole mass to the sea. If they had not this removing power, their channels would be annually choked up, and the valleys of the lower country, and plains at the base of mountain-chains, would be continually strewed over with fragments of rock and sterile sand. But this evil is prevented by a general law regulating the conduct of

* Encyc. Brit. — art. Rivers.

running water,—that two equal streams do not, when united, occupy a bed of double surface. In other words, when several rivers unite into one, the superficial area of the fluid mass is far less than that previously occupied by the separate streams. The collective waters, instead of spreading themselves out over a larger horizontal space, contract themselves into a column of which the height is greater relatively to its breadth. Hence the main current is often accelerated in the lower country, even where the slope of the river's bed is lessened, a smaller proportion of the whole being retarded by friction against the bottom and sides of the channel, and in this manner the stream is enabled to force its way against all obstructions, and gradually to remove the matter swept down into it from the upland regions.

It not unfrequently happens, as will be afterwards demonstrated by examples, that two large rivers, after their junction, have only the *surface* which one of them had previously; and even in some cases their united waters are confined in a narrower bed than each of them filled before. By this beautiful adjustment, the water which drains the interior country is made continually to occupy less room as it approaches the sea; and thus the most valuable part of our continents, the rich deltas, and great alluvial plains, are prevented from being constantly under water.*

River-floods in Scotland, 1829.—Many remarkable illustrations of the power of running water in moving stones and heavy materials were afforded by the storm and floods which occurred on the 3d and 4th of August, 1829, in Aberdeenshire and other counties in Scotland.

* See article *Rivers*, Encyc. Brit.

The elements during this storm assumed all the characters which mark the tropical hurricanes; the wind blowing in sudden gusts and whirlwinds, the lightning and thunder being such as is rarely witnessed in our climate, and heavy rain falling without intermission. The floods extended almost simultaneously, and with equal violence, over that part of the north-east of Scotland which would be cut off by two lines drawn from the head of Lochrannoch, one towards Inverness and the other to Stonehaven. The united line of the different rivers which were flooded could not be less than from five to six hundred miles in length; and the whole of their courses were marked by the destruction of bridges, roads, crops, and buildings. Sir T. D. Lauder has recorded the destruction of thirty-eight bridges, and the entire obliteration of a great number of farms and hamlets. On the Nairn, a fragment of sandstone, fourteen feet long by three feet wide and one foot thick, was carried above 200 yards down the river. Some new ravines were formed on the sides of mountains where no streams had previously flowed, and ancient river channels, which had never been filled from time immemorial, gave passage to a copious flood.*

The bridge over the Dee at Ballater consisted of five arches, having upon the whole a water-way of 260 feet. The bed of the river, on which the piers rested, was composed of rolled pieces of granite and gneiss. The bridge was built of granite, and had stood uninjured for twenty years; but the different parts were swept away in succession by the flood, and the whole

* Sir T. D. Lauder's Account of the Great Floods in Morayshire, Aug. 1829.

mass of masonry disappeared in the bed of the river. "The river Don," observes Mr. Farquharson, in his account of the inundations, "has upon my own premises forced a mass of four or five hundred tons of stones, many of them two or three hundred pounds' weight, up an inclined plane, rising six feet in eight or ten yards, and left them in a rectangular heap, about three feet deep, on a flat ground; — the heap ends abruptly at its lower extremity." *

The power even of a small rivulet, when swoln by rain, in removing heavy bodies, was lately exemplified (August, 1827,) in the College, a small stream which flows at a moderate declivity from the eastern watershed of the Cheviot Hills. Several thousand tons' weight of gravel and sand were transported to the plain of the Till, and a bridge, then in progress of building, was carried away, some of the arch-stones of which, weighing from half to three quarters of a ton each, were propelled two miles down the rivulet. On the same occasion, the current tore away from the abutment of a mill-dam a large block of greenstone-porphyry, weighing nearly two tons, and transported it to the distance of a quarter of a mile. Instances are related as occurring repeatedly, in which from one to three thousand tons of gravel are, in like manner, removed by this streamlet to still greater distances in one day.†

In the cases above adverted to, the waters of the river and torrent were dammed back by the bridges, which acted as partial barriers, and illustrate the irresistible force of a current when obstructed. Bridges

* Quarterly Journ. of Sci. &c. No. xii. New Series, p. 331.

† See a paper by Mr. Culley, F.G. S. Proceedings of Geol. Soc. No. 12. 1829.

are also liable to be destroyed by the tendency of rivers to shift their course, whereby the pier, or the rock on which the foundation stands, is undermined.

Excavation of rocks by running water.—The rapidity with which even the smallest streams hollow out deep channels in soft and destructible soils is remarkably exemplified in volcanic countries, where the sand and half-consolidated tuffs oppose but a slight resistance to the torrents which descend the mountain side. After the heavy rains which followed the eruption of Vesuvius in 1824, the water flowing from the Atrio del Cavallo cut, in three days, a new chasm through strata of tuff and ejected volcanic matter, to the depth of twenty-five feet. I found the old mule-road, in 1828, intersected by this new ravine.

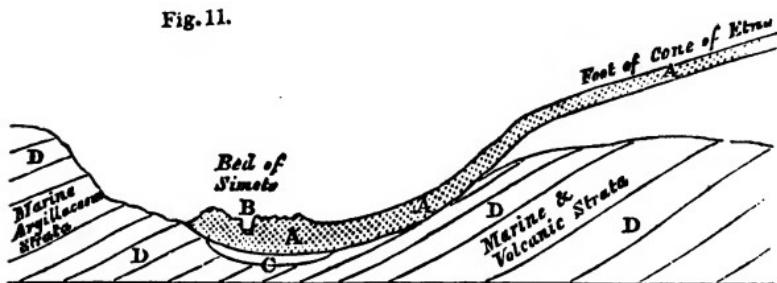
The gradual erosion of deep chasms through some of the hardest rocks, by the constant passage of running water, charged with foreign matter, is another phenomenon of which striking examples may be adduced. Illustrations of this excavating power are presented by many valleys in central France, where the channels of rivers have been barred up by solid currents of lava, through which the streams have re-excavated a passage to the depth of from twenty to seventy feet and upwards, and often of great width. In these cases there are decisive proofs that neither the sea, nor any denuding wave or extraordinary body of water, has passed over the spot since the melted lava was consolidated. Every hypothesis of the intervention of sudden and violent agency is entirely excluded, because the cones of *loose* scoriæ, out of which the lavas flowed, are oftentimes at no great elevation above the rivers, and have remained undis-

turbed during the whole period which has been sufficient for the hollowing out of such enormous ravines.

Recent excavation by the Simeto. — But I shall at present confine myself to examples derived from events which have happened since the time of history.

At the western base of Etna, a current of lava (A A, fig. 11.), descending from near the summit of the great volcano, has flowed to the distance of five or six miles, and then reached the alluvial plain of the

Fig. 11.



Recent excavation of lava at the foot of Etna by the river Simeto.

Simeto, the largest of the Sicilian rivers, which skirts the base of Etna, and falls into the sea a few miles south of Catania. The lava entered the river about three miles above the town of Aderno, and not only occupied its channel for some distance, but, crossing to the opposite side of the valley, accumulated there in a rocky mass. Gemmellaro gives the year 1603 as the date of the eruption.* The appearance of the current clearly proves that it is one of the most modern of those of Etna : for it has not been covered or crossed by subsequent streams or ejections, and the olives which have been planted on its surface are all

* *Quadro Istorico dell' Etna*, 1824. Some doubts are entertained as to the exact date of this current by others, but all agree that it is not one of the older streams even of the historical era.

of small size, yet older than the natural wood on the same lava. In the course, therefore, of about two centuries, the Simeto has eroded a passage from fifty to several hundred feet wide, and in some parts from forty to fifty feet deep.

The portion of lava cut through is in no part porous or scoriaceous, but consists of a compact homogeneous mass of hard blue rock, somewhat inferior in weight to ordinary basalt, and containing crystals of olivine and glassy felspar. The general declivity of this part of the bed of the Simeto is not considerable; but, in consequence of the unequal waste of the lava, two waterfalls occur at Passo Manzanelli, each about six feet in height. Here the chasm (b, fig. 11.) is about forty feet deep, and only fifty broad.

The sand and pebbles in the river-bed consist chiefly of a brown quartzose sandstone, derived from the upper country; but the materials of the volcanic rock itself must have greatly assisted the attrition. This river, like the Caltabiano on the eastern side of Etna, has not yet cut down to the ancient bed of which it was dispossessed, and of which the probable position is indicated in the annexed diagram (c, fig. 11.).

On entering the narrow ravine where the water foams down the two cataracts, we are entirely shut out from all view of the surrounding country; and a geologist who is accustomed to associate the characteristic features of the landscape with the relative age of certain rocks, can scarcely dissuade himself from the belief that he is contemplating a scene in some rocky gorge of a primary district. The external forms of the hard blue lava are as massive as any of the most ancient trap-rocks of Scotland. The solid surface is in

some parts smoothed and almost polished by attrition, and covered in others with a white lichen, which imparts to it an air of extreme antiquity, so as greatly to heighten the delusion. But the moment we re-ascend the cliff the spell is broken : for we scarcely recede a few paces, before the ravine and river disappear, and we stand on the black and rugged surface of a vast current of lava, which seems unbroken, and which we can trace up nearly to the distant summit of that majestic cone which Pindar called "the pillar of heaven," and which still continues to send forth a fleecy wreath of vapour, reminding us that its fires are not extinct, and that it may again give out a rocky stream, wherein other scenes like that now described may present themselves to future observers.

Falls of Niagara. — The falls of Niagara afford a magnificent example of the progressive excavation of a deep valley in solid rock. That river flows from Lake Erie to Lake Ontario, the former lake being 330 feet above the latter, and the distance between them being thirty-two miles. On flowing out of the upper lake, the river is almost on a level with its banks ; so that if it should rise perpendicularly eight or ten feet, it would lay under water the adjacent flat country of Upper Canada on the West, and of the State of New York on the East.* The river, where it issues, is about three quarters of a mile in width. Before reaching the Falls, it is propelled with great rapidity, being a mile broad, about twenty-five feet deep, and having a descent of fifty feet in half a mile. An island at the very verge of the cataract divides it into two sheets of water: one of these, called the

* Captain Hall's Travels in North America, vol. i. p. 179.

Horse-shoe Fall, is six hundred yards wide, and 158 feet perpendicular; the other, called the American Falls, is about two hundred yards in width, and 164 feet in height. The breadth of the island is about five hundred yards. This great sheet of water is precipitated over a ledge of hard limestone, in horizontal strata, below which is a somewhat greater thickness of soft shale, which decays and crumbles away more rapidly, so that the calcareous rock forms an overhanging mass, projecting forty feet or more above the hollow space below.

The blasts of wind, charged with spray, which rise out of the pool into which this enormous cascade is projected, strike against the shale beds, so that their disintegration is constant. They also waste away at certain seasons by the expansive action of frost. The superincumbent limestone, being thus left without a foundation, falls from time to time in rocky masses. When these enormous fragments descend, a shock is felt at some distance, accompanied by a noise like a distant clap of thunder. After the river has passed over the falls, its character, observes Captain Hall, is immediately and completely changed. It then runs furiously along the bottom of a deep wall-sided valley, or huge trench, which has been cut into the horizontal strata by the continued action of the stream during the lapse of ages. The bed of the river here is strewed over with huge fragments of rock; the cliffs on both sides are in most places perpendicular, and the ravine is only perceived on approaching the edge of the precipice.*

The waters, which expand at the falls, where they are divided by the island, are contracted again, after

* Hall's Travels in North America, vol. i. pp. 195, 196. 216.

their union, into a stream not more than 160 yards broad. It is remarkable that the water of the pool into which the cataract is precipitated, and that of the narrow channel immediately below, instead of being in a state of tremendous agitation, is so tranquil as to allow a ferry boat to cross with ease, and even to approach within the reach of the spray, without experiencing any unusual motion. Various explanations have been offered of this phenomenon. According to Mr. Gibson the vast body of sea-green water, instead of plunging deep as a solid column would do into the sheet below, is drawn out in its descent of 160 feet into white rolls of attenuated foam. He conceives, therefore, that most of the water falls lightly in the form of spray, and the force of the rest is broken by the debris which lie immediately at the foot of the fall.*

Recession of the Falls. — When the Falls were visited in 1829 by Mr. R. Bakewell, jun., he ascertained from a person who had lived forty years in that part of the country, and had been the first settler there, that during that period the Falls on the Canada side had receded forty or fifty yards, in consequence of the continued removal of the shale, and undermining of the limestone, above described.† As the ravine, therefore, below the Falls has been thus prolonged, and as that part of the chasm which has been the work of the last half century resembles in depth and width the average dimensions of the ravine below ‡, it is natural to in-

* Silliman's American Journal, vol. xxix. p. 206.

† The memoir of Mr. Bakewell contains two very illustrative sketches of the physical geography of the country between Lakes Erie and Ontario, including the Falls. — Loudon's Mag. of Nat. Hist. No. 12. March, 1830.

‡ See Professor Rogers, Silliman's American Journal, vol. xxvii. p. 326.

quire how long this same process may have continued; and where did the retrogression of the cataract commence? The ravine through which the Niagara flows continues for about seven miles below the Falls, the perpendicular banks maintaining throughout their whole length an average elevation of two hundred feet, for the land above declines gently at the same rate as the bed of the river, which falls 104 feet in its course of seven miles.* The table-land, which is almost on a level with Lake Erie, after sloping insensibly for the space above mentioned, comes suddenly to a termination at Queenstown, where on both sides of the river an abrupt slope, like an inland sea-cliff, is seen extending east and west. At this point the river emerges from the ravine into a plain, which continues to the shores of Lake Ontario. Now it has been a very general opinion that the Falls were once at Queenstown, and that they have gradually retrograded from that place to their present position about seven miles distant. For the table-land extending from Queenstown to Lake Erie consists uniformly of the same geological formations as are now exposed to view at the Falls. The upper deposit is a fresh-water formation, consisting chiefly of gravel, containing fragments of limestone and other transported rocks, with a few feet of fine clay below. The fresh-water shells are said to agree in species with those now inhabiting Lake Erie. Below this superficial covering is rock of hard limestone, about ninety feet in thickness, stretching nearly in a horizontal direction over the whole country, and forming the bed of the river above the Falls, as do the inferior shales below.

* See Professor Rogers, Silliman's American Journal, vol. xxvii. p. 328.

If the recession of the Falls had always proceeded at the rate of about fifty yards in forty years, it would have required, says Mr. Bakewell, nearly ten thousand years for the excavation of the whole ravine, seven miles in length ; but Professor Rogers, Mr. Hayes, and other American writers have justly observed, that our calculations of the time employed in the excavation of the ravine must always be extremely uncertain while we remain ignorant of the exact topographical features of the district when it first emerged from the waters, whether of a lake or sea. Part of the ravine may have coincided originally with some rent in the rocks, afterwards enlarged by tides and currents during the gradual upheaval of the country, and before the existence of the river. Mr. Hayes states that between the Falls and Queenstown there is in one place a short lateral indentation, branching off from the principal ravine, which the cataract could not have shaped out, and which therefore implies the former agency of other causes. *

It seems equally difficult to speculate on the future rate of recession of the Falls, for as they retreat the height of the precipice may be reduced or augmented by the varying hardness of the rocks, the division of the stream by islands, and other modifying circumstances.

If in the course of many thousand years the Falls should reach Lake Erie, twenty-five miles distant, that lake might be effectually drained, inasmuch as the present height of the Falls far exceeds the greatest depth of the lake. It has been supposed that in this case the sudden escape of the water might occasion a deluge on the low lands bordering Ontario ; but in reply, Mr.

* Silliman's American Journal, vol. xxxv. p. 102.

De la Beche has objected, that as the bottom of Lake Erie shelves verygently from the shore, the discharge, even after the cataract had receded to the lake, would take place gradually, and it would require time before the river channel was cut back to where the water is deepest.*

It may also be questioned whether the entire area of Lake Erie may not be converted into dry land before the Falls recede to its shores, so shallow is this lake, its average depth being only ten or twelve fathoms, and so fast is it filling up with sediment.

* De la Beche, Geol. Manual, 3d edit. p. 60. Rogers, Silliman's American Journal, vol. xxvii. p. 332.

CHAPTER II.

ACTION OF RUNNING WATER — *continued.*

Course of the Po — Desertion of its old channel — Artificial embankments of the Po, Adige, and other Italian rivers — Basin of the Mississippi — Its meanders — Islands — Shifting of its course — Raft of the Atchafalaya — Drift wood — New formed lakes in Louisiana — Earthquakes in valley of Mississippi — Floods caused by land-slips in the White Mountains — Bursting of a lake in Switzerland — Devastations caused by the Anio at Tivoli.

Course of the Po. — THE Po affords an instructive example of the manner in which a great river bears down to the sea the matter poured into it by a multitude of tributaries descending from lofty chains of mountains. The changes gradually effected in the great plain of Northern Italy, since the time of the Roman republic, are considerable. Extensive lakes and marshes have been gradually filled up, as those near Placentia, Parma, and Cremona, and many have been drained naturally by the deepening of the beds of rivers. Deserted river-courses are not unfrequent, as that of the Serio Morto, which formerly fell into the Adda, in Lombardy ; and the Po itself has often deviated from its course. Subsequently to the year 1390, it deserted part of the territory of Cremona, and invaded that of Parma ; its old channel being still recognizable, and bearing the name of Po Morto. Bressello is one of the towns of which the site was formerly on the left of the Po, but which is now on

the right bank. There is also an old channel of the Po in the territory of Parma, called Po Vecchio, which was abandoned in the twelfth century, when a great number of towns were destroyed. There are records of parish churches, as those of Vicobellignano, Agojolo, and Martignana, having been pulled down and afterwards rebuilt at a greater distance from the devouring stream. In the fifteenth century the main branch again resumed its deserted channel, and carried away a great island opposite Casalmaggiore. At the end of the same century it abandoned, a second time, the bed called "Po Vecchio," carrying away three streets of Casalmaggiore. The friars in the monastery de' Serviti, took the alarm in 1471, demolished their buildings, and reconstructed them at Fontana, whither they had transported the materials. In like manner, the church of S. Rocco was demolished in 1511. In the seventeenth century also the Po shifted its course for a mile in the same district, causing great devastations.*

Artificial embankments of Italian rivers.—To check these and similar aberrations, a general system of embankment has been adopted; and the Po, Adige, and almost all their tributaries, are now confined between high artificial banks. The increased velocity acquired by streams thus closed in enables them to convey a much larger portion of foreign matter to the sea; and, consequently, the deltas of the Po and Adige have gained far more rapidly on the Adriatic since the practice of embankment became almost universal. But, although more sediment is borne to the sea, part of the sand and mud, which in the natural state of

* Dell' Antico Corso de' Fiumi Po, Oglio, ed Adda, dell' Giovanni Romani. Milan, 1828.

things would be spread out by annual inundations over the plain, now subsides in the bottom of the river-channels; and their capacity being thereby diminished, it is necessary, in order to prevent inundations in the following spring, to extract matter from the bed, and to add it to the banks of the river. Hence it happens that these streams now traverse the plain on the top of high mounds, like the waters of aqueducts, and at Ferrara the surface of the Po has become more elevated than the roofs of the houses.* The magnitude of these barriers is a subject of increasing expense and anxiety, it having been sometimes found necessary to give an additional height of nearly one foot to the banks of the Adige and Po in a single season.

The practice of embankment was adopted on some of the Italian rivers as early as the thirteenth century; and Dante, writing in the beginning of the fourteenth, describes, in the seventh circle of hell, a rivulet of tears separated from a burning sandy desert by embankments "like those which, between Ghent and Bruges, were raised against the ocean, or those which the Paduans had erected along the Brenta to defend their villas on the melting of the Alpine snows."

Quale i Fiamminghi tra Guzzante e Bruggia,
Temendo il fiotto che in ver lor s'avventa,
Fanno lo schermo, perchè il mar si fuggia,
E quale i Padovan lungo la Brenta,
Per difender lor ville e lor castelli,
Anzi che Chiarentana il caldo senta —

Inferno, Canto xv.

Basin of the Mississippi.—The hydrographical basin of the Mississippi displays, on the grandest scale, the

* Prony, see Cuvier, Disc. Prélim. p. 146.

action of running water on the surface of a vast continent. This magnificent river rises nearly in the forty-ninth parallel of north latitude, and flows to the Gulf of Mexico in the twenty-ninth — a course, including its meanders, of nearly five thousand miles. It passes from a cold arctic climate, traverses the temperate regions, and discharges its waters into the sea in the region of the olive, the fig, and the sugar-cane.* No river affords a more striking illustration of the law before mentioned, that an augmentation of volume does not occasion a proportional increase of surface, nay, is even sometimes attended with a narrowing of the channel. The Mississippi is half a mile wide at its junction with the Missouri†, the latter being also of equal width; yet the united waters have only, from their confluence to the mouth of the Ohio, a medial width of about three quarters of a mile. The junction of the Ohio seems also to produce no increase, but rather a decrease, of surface.‡ The St. Francis, White, Arkansas, and Red rivers, are also absorbed by the main stream with scarcely any apparent increase of its width; and, on arriving near the sea at New Orleans, it is somewhat less than half a mile wide. Its depth there is very variable, the greatest at high water being 168 feet. The mean rate at which the whole body of water flows is variously estimated. According to some, it does not exceed one mile an hour.§

* Flint's Geography, vol. i. p. 21.

† Flint says (vol. i. p. 140.) that, where the Mississippi receives the Missouri, it is a mile and a half wide, but, according to Captain B. Hall, this is a great mistake. — Travels in North America, vol. iii. p. 328.

‡ Flint's Geography, vol. i. p. 142.

§ Hall's Travels in North America, vol. iii. p. 330., who cites Darby.

The alluvial plain of this great river is bounded on the east and west by great ranges of mountains stretching along their respective oceans. Below the junction of the Ohio, the plain is from thirty to fifty miles broad, and after that point it goes on increasing in width, till the expanse is perhaps three times as great! On the borders of this vast alluvial tract are perpendicular cliffs, or "bluffs," as they are called, sometimes three hundred feet or more in height, composed of limestone and other rocks, and often of alluvium. For a great distance the Mississippi washes the eastern "bluffs;" and below the mouth of the Ohio, never once comes in contact with the western. The waters are thrown to the eastern side, because all the large tributary rivers entering from the west, have filled that side of the great valley with a sloping mass of clay and sand. For this reason, the eastern bluffs are continually undermined, and the Mississippi is slowly but incessantly progressing eastward.*

Curves of the Mississippi.—The river traverses the plain in a meandering course, describing immense and uniform curves. After sweeping round the half of a circle, it is carried in a rapid current diagonally across its own channel, to another curve of the same uniformity upon the opposite shore.† These curves are so regular, that the boatmen and Indians calculate distances by them. Opposite to each of them there is always a sand-bar, answering, in the convexity of its form, to the concavity of "the bend," as it is called.‡ The river, by continually wearing these

* Geograph. Descrip. of the State of Louisiana, by W. Darby, Philadelphia, 1816, p. 102.

† Flint's Geog. vol. i. p. 152.

‡ Ibid.

curves deeper, returns, like many other streams before described, on its own tract, so that a vessel in some places, after sailing for twenty-five or thirty miles, is brought round again to within a mile of the place whence it started. When the waters approach so near to each other, it often happens at high floods that they burst through the small tongue of land, and insulate a portion, rushing through what is called the "cut off" with great velocity. At one spot, called the "grand cut off," vessels now pass from one point to another in half a mile to a distance which it formerly required a voyage of twenty miles to reach.*

Waste of its banks. — After the flood season, when the river subsides within its channel, it acts with destructive force upon the alluvial banks, softened and diluted by the recent overflow. Several acres at a time, thickly covered with wood, are precipitated into the stream; and large portions of the islands formed by the process before described are swept away.

"Some years ago," observes Captain Hall, "when the Mississippi was regularly surveyed, all its islands were numbered, from the confluence of the Missouri to the sea; but every season makes such revolutions, not only in the number but in the magnitude and situation of these islands, that this enumeration is now almost obsolete. Sometimes large islands are entirely melted away — at other places they have attached themselves to the main shore, or, which is the more correct statement, the interval has been filled up by myriads of logs cemented together by mud and rubbish." † When the Mississippi and many

* Flint's Geog. vol. i. p. 154.

† Travels in North America, vol. iii. p. 361.

of its great tributaries overflow their banks, the waters, being no longer borne down by the main current, and becoming impeded amongst the trees and bushes, deposit the sediment of mud and sand with which they are abundantly charged. Islands arrest the progress of floating trees, and they often become in this manner re-united to the land; the rafts of trees, together with mud, constituting at length a solid mass. The coarser and more sandy portion is thrown down first nearest the banks; and finer particles are deposited at the farthest distances from the river, where an impalpable mixture subsides, forming a stiff unctuous black soil. Hence, in the alluvial plains of these rivers the land slopes back, like a natural glacis towards the cliffs bounding the great valley (see fig. 12.), and during



a, Channel of the river.

b, Base of the "bluffs."

inundations the highest part of the banks form narrow strips of dry ground, rising above the river on one side, and above the low flooded country on the other. The Mississippi, therefore, has been described as a river running on the top of a long hill or ridge, which has an elevation of twenty-four feet in its highest part, and a base three miles in average diameter. Flint, however, remarks, that this picture is not very correct, for, notwithstanding the comparative elevation of the banks, the deepest part of the bed of the river (*a*, fig. 12.) is uniformly lower than the lowest point of the alluvium at the base of the bluffs.*

It has been said of a mountain torrent, that "it lays down what it will remove, and removes what it has

* Flint's Geography, vol. i. p. 151.

laid down ;" and in like manner the Mississippi, by the continual shifting of its course, sweeps away, during a great portion of the year, considerable tracts of alluvium, which were gradually accumulated by the overflow of former years, and the matter now left during the spring-floods will be at some future time removed.

Rafts.—One of the most interesting features in the great rivers of this part of America is the frequent accumulation of what are termed "rafts," or masses of floating trees, which have been arrested in their progress by snags, islands, shoals, or other obstructions, and made to accumulate, so as to form natural bridges reaching entirely across the stream. One of the largest of these was called the raft of the Atchafalaya, an arm of the Mississippi, which was certainly at some former time the channel of the Red River, when the latter found its way to the Gulf of Mexico by a separate course. The Atchafalaya being in a direct line with the general direction of the Mississippi, catches a large portion of the timber annually brought down from the north ; and the drift trees collected in about thirty-eight years previous to 1816 formed a continuous raft, no less than ten miles in length, 220 yards wide, and eight feet deep. The whole rose and fell with the water, yet was covered with green bushes and trees, and its surface enlivened in the autumn by a variety of beautiful flowers. It went on increasing till about 1835, when some of the trees upon it had grown to the height of about sixty feet. Steps were then taken by the state of Louisiana to clear away the whole raft and open the navigation, which was effected, not without great labour, in the space of four years.

The rafts on Red River are equally remarkable ; in

some parts of its course, cedar trees are heaped up by themselves, and in other places pines. There is also a raft on the Washita, the principal tributary of the Red River, which seriously interrupts the navigation, concealing the whole river for seventeen leagues. This natural bridge is described in 1804 as supporting all the plants then growing in the neighbouring forest, not excepting large trees; and so perfectly was the stream concealed by the superincumbent mass, that it might be crossed in some places without any knowledge of its existence.*

Drift Wood.—In addition to the astonishing number of cubic feet of timber arrested by the rafts, great deposits are unceasingly in progress at the extremity of the delta in the Bay of Mexico. “Unfortunately for the navigation of the Mississippi,” observes Captain Hall, “some of the largest trunks, after being cast down from the position on which they grew, get their roots entangled with the bottom of the river, where they remain anchored, as it were, in the mud. The force of the current naturally gives their tops a tendency downwards, and, by its flowing past, soon strips them of their leaves and branches. These fixtures, called snags or planters, are extremely dangerous to the steam-vessels proceeding up the stream, in which they lie like a lance in rest, concealed beneath the water, with their sharp ends pointed directly against the bow of the vessels coming up. For the most part these formidable snags remain so still, that they can be detected only by a slight ripple above them, not perceptible to inexperienced eyes. Sometimes, however, they vibrate up and down, alternately

* *Navigator*, p. 263. Pittsburgh, 1821.

showing their heads above the surface, and bathing them beneath it."* So imminent is the danger caused by these obstructions, that almost all the boats on the Mississippi are constructed on a particular plan, to guard against fatal accidents. †

The prodigious quantity of wood annually drifted down by the Mississippi and its tributaries, is a subject of geological interest, not merely as illustrating the manner in which abundance of vegetable matter becomes, in the ordinary course of nature, imbedded in submarine and estuary deposits, but as attesting the constant destruction of soil and transportation of matter to lower levels by the tendency of rivers to shift their courses. Each of these trees must have required many years, some of them centuries, to attain their full size; the soil, therefore, whereon they grew, after remaining undisturbed for long periods, is ultimately torn up and swept away. Yet, notwithstanding this incessant destruction of land and up-rooting of trees, the region which yields this never-failing supply of drift wood is densely clothed with noble forests, and is almost unrivalled in its power of supporting animal and vegetable life.

Innumerable herds of wild deer and bisons feed on the luxurious pastures of the plains. The puma, the

* Travels in North America, vol. iii. p. 362.

† "The boats are fitted," says Captain Hall, "with what is called a snag-chamber; — a partition formed of stout planks, which is caulked, and made so effectually water-tight, that the foremost end of the vessel is cut off as entirely from the rest of the hold as if it belonged to another boat. If the steam-vessel happen to run against a snag, and that a hole is made in her bow, under the surface, this chamber merely fills with water." Travels in North America, vol. iii. p. 363.

wolf, and the fox, are amongst the beasts of prey. The waters teem with alligators and tortoises, and their surface is covered with millions of migratory water-fowl, which perform their annual voyage between the Canadian lakes and the shores of the Mexican Gulf. The power of man begins to be sensibly felt, and the wilderness to be replaced by towns, orchards, and gardens. The gilded steam-boat, like a moving city, now stems the current with a steady pace — now shoots rapidly down the descending stream, through the solitudes of the forests and prairies. Already does the flourishing population of the great valley exceed that of the thirteen United States when first they declared their independence, and, after a sanguinary struggle, were severed from the parent country.* Such is the state of a continent where rocks and trees are hurried annually, by a thousand torrents, from the mountains to the plains, and where sand and finer matter are swept down by a vast current to the sea, together with the wreck of countless forests and the bones of animals which perish in the inundations. When these materials reach the Gulf, they do not render the waters unfit for aquatic animals; but, on the contrary, the ocean here swarms with life, as it generally does where the influx of a great river furnishes a copious supply of organic and mineral matter. Yet many geologists, when they behold the spoils of the land heaped in successive strata, and blended confusedly with the remains of fishes, or interspersed with broken shells and corals, imagine that they are viewing the signs of a turbulent instead of a tranquil and settled state of the planet.

* Flint's Geography, vol. i.

They read in such phenomena the proof of chaotic disorder, and reiterated catastrophes, instead of indications of a surface as habitable as the most delicious and fertile districts now tenanted by man. They are not content with disregarding the analogy of the present course of Nature, when they speculate on the revolutions of past times, but they often draw conclusions, concerning the former state of things, directly the reverse of those to which a fair induction from facts would infallibly lead them.

Formation of lakes in Louisiana.—Another striking feature in the basin of the Mississippi, illustrative of the changes now in progress, is the formation by natural causes of great lakes, and the drainage of others. These are especially frequent in the basin of the Red River in Louisiana, where the largest of them, called Bistineau, is more than *thirty miles* long, and has a medium depth of from *fifteen to twenty* feet. In the deepest parts are seen numerous cypress trees, of all sizes, now dead, and most of them with their tops broken by the wind, yet standing erect under water. This tree resists the action of air and water longer than any other, and, if not submerged throughout the whole year, will retain life for an extraordinary period. Lake Bistineau, as well as Black Lake, Cado Lake, Spanish Lake, Natchitoches Lake, and many others, have been formed, according to Darby, by the gradual elevation of the bed of Red River, in which the alluvial accumulations have been so great as to raise its channel, and cause its waters, during the flood season, to flow up the mouths of many tributaries, and to convert parts of their courses into lakes. In the autumn, when the level of Red River is again depressed, the waters rush back, and some lakes

become grassy meadows, with streams meandering through them.* Thus, there is a periodical flux and reflux between Red River and some of these basins, which are merely reservoirs, alternately emptied and filled, like our tide estuaries — with this difference, that in the one case the land is submerged for several months continuously, and in the other twice in every twenty-four hours. It has happened, in several cases, that a raft of timber or a bar has been thrown by Red River across some of the openings of these channels, and then the lakes become, like Bistineau, constant repositories of water. But even in these cases, their level is liable to annual elevation and depression, because the flood of the main river, when at its height, passes over the bar; just as, where sand-hills close the entrance of an estuary on the Norfolk or Suffolk coast, the sea, during some high tide or storm, has often breached the barrier and inundated again the interior.

I am informed by Mr. Featherstonhaugh that the plains of the Red River and the Arkansas are so low and flat, that whenever the Mississippi rises thirty feet above its ordinary level, those great tributaries are made to flow back, and inundate a region of vast extent. Both the streams alluded to contain red sediment, derived from the decomposition of red porphyry, and since 1833, when there was a great inundation in the Arkansas, an immense swamp has been formed near the Mammelle mountain, comprising 30,000 acres, with here and there large lagoons where the old bed of the river was situated; in which innumerable trees, for the most part dead, are seen standing, of cypress, cot-

* Darby's Louisiana, p. 33.

ton wood, poplar, the triple thorned acacia, and others, which are of great size. Their trunks appear as if painted red for about fifteen feet from the ground; at which height a perfectly level line extends through the whole forest, marking the rise of the waters during the last flood.*

Perhaps the cause above assigned for the recent origin of these lakes is not the only one. Subterranean movements have altered, so lately as the year 1812, the relative levels of various parts of the basin of the Mississippi, situated about 100 leagues N. E. of Lake Bistineau. In that year the great valley, from the mouth of the Ohio to that of the St. Francis, including a tract 300 miles in length, and exceeding in area the whole basin of the Thames, was convulsed to such a degree, as to create new islands in the river, and lakes in the alluvial plain, some of which were *twenty miles in extent*. Old trees were seen submerged in two of these lakes, called Reelfoot and Obion, about twenty years afterwards.†

Analogous facts have been observed in other parts of N. America. Thus Captains Clark and Lewis found, about the year 1807, a forest of pines standing erect under water in the body of the Columbia river, which they supposed, from the appearance of the trees, to have been submerged only about twenty years.‡ More lately (1835) the Rev. Mr. Parker observed on the same river (lat. 45° N., long. 121° W.) trees standing in their natural position in spots where the water was more than twenty feet deep. The tops of the trees had disappeared, but between high and low

* Featherstonhaugh, Geol. Report, Washington, 1835, p. 84.

† Usher, Silliman's Journal, vol. xxxi. p. 295.

‡ Travels, &c., vol. ii. p. 241.

water mark the trunks were only partially decayed, a fact which proves their submergence to have taken place at a comparatively recent date. The roots were seen through the clear water, spreading as they had grown in their native forest, and from the space which the trees covered it was inferred that a tract of land, more than twenty miles in length and above a mile in width, must have subsided tranquilly.*

FLOODS, BURSTING OF LAKES, ETC.

The power which running water may exert, in the lapse of ages, in widening and deepening a valley, does not so much depend on the volume and velocity of the stream usually flowing in it, as on the number and magnitude of the obstructions which have, at different periods, opposed its free passage. If a torrent, however small, be effectually dammed up, the size of the valley above the barrier, and its declivity below, and not the dimensions of the torrent, will determine the violence of the débâcle. The most universal source of local deluges are landslips, slides, or avalanches, as they are sometimes called, when great masses of rock and soil, or sometimes ice and snow, are precipitated into the bed of a river, the boundary cliffs of which have been thrown down by the shock of an earthquake, or undermined by springs or other causes. Volumes might be filled with the enumeration of instances on record of these terrific catastrophes; I shall therefore select a few examples of recent occurrence, the facts of which are well authenticated.

Floods caused by landslips, 1826.—Two dry seasons in the White Mountains, in New Hampshire, were fol-

* Tour beyond the Rocky Mountains, p. 132.

lowed by heavy rains on the 28th August, 1826, when from the steep and lofty declivities which rise abruptly on both sides of the river Saco, innumerable rocks and stones, many of sufficient size to fill a common apartment, were detached, and in their descent swept down before them, in one promiscuous and frightful ruin, forests, shrubs, and the earth which sustained them. No tradition existed of any similar slides at former times, and the growth of the forest on the flanks of the hills clearly showed that for a long interval nothing similar had occurred. One of these moving masses was afterwards found to have slid three miles, with an average breadth of a quarter of a mile. The natural excavations commenced generally in a trench a few yards in depth and a few rods in width, and descended the mountains, widening and deepening till they became vast chasms. At the base of these hollow ravines was seen a wide and deep mass of ruins, consisting of transported earth, gravel, rocks, and trees. Forests of spruce-fir and hemlock were prostrated with as much ease as if they had been fields of grain; for, where they disputed the ground, the torrent of mud and rock accumulated behind till it gathered sufficient force to burst the temporary barrier.

The valleys of the Amonoosuck and Saco presented, for many miles, an uninterrupted scene of desolation; all the bridges being carried away, as well as those over their tributary streams. In some places, the road was excavated to the depth of from fifteen to twenty feet; in others, it was covered with earth, rocks, and trees, to as great a height. The water flowed for many weeks after the flood, as densely charged with earth as it could be without being changed into mud, and marks were seen in various localities of its having

risen on either side of the valley to more than twenty-five feet above its ordinary level. Many sheep and cattle were swept away, and the Willey family, nine in number, who in alarm had deserted their house, were destroyed on the banks of the Saco; seven of their mangled bodies were afterwards found near the river, buried beneath drift wood and mountain ruins.* Eleven years after the event the deep channels worn by the avalanches of mud and stone, and the immense heaps of boulders and blocks of granite in the river channel, still formed, says Professor Hubbard, a picturesque feature in the scenery.†

But these catastrophes are insignificant, when compared to those which are occasioned by earthquakes, when the boundary hills, for miles in length, are thrown down into the hollow of a valley. I shall have opportunities of alluding to inundations of this kind when treating expressly of earthquakes, and shall content myself at present with selecting an example, of modern date, of a flood caused by the bursting of a temporary lake, the facts having been described, with more than usual accuracy, by scientific observers.

Flood in the valley of Bagne, 1818. — The valley of Bagne is one of the largest of the lateral embrangements of the main valley of the Rhone, above the Lake of Geneva. Its upper portion was, in 1818, converted into a lake by the damming up of a narrow pass, by avalanches of snow and ice, precipitated from an elevated glacier into the bed of the river Dranse. In the winter season, during continued frost, scarcely any water flows in the bed of this river to

* Silliman's Journal, vol. xv. No. 2. p. 216. Jan. 1829.

† Ibid. vol. xxxiv. p. 115.

preserve an open channel, so that the ice barrier remained entire until the melting of the snows in spring, when a lake was formed above, about half a league in length, which finally attained in some parts a depth of about two hundred feet, and a width of about seven hundred feet. To prevent or lessen the mischief apprehended from the sudden bursting of the barrier, an artificial gallery, seven hundred feet in length, was cut through the ice, before the waters had risen to a great height. When at length they accumulated and flowed through this tunnel, they dissolved the ice, and thus deepened their channel, until nearly half of the whole contents of the lake were slowly drained off. But at length, on the approach of the hot season, the central portion of the remaining mass of ice gave way with a tremendous crash, and the residue of the lake was emptied in half an hour. In the course of its descent, the waters encountered several narrow gorges, and at each of these they rose to a great height, and then burst with new violence into the next basin, sweeping along rocks, forests, houses, bridges, and cultivated land. For the greater part of its course the flood resembled a moving mass of rock and mud, rather than of water. Some fragments of granitic rocks, of enormous magnitude, and which, from their dimensions, might be compared without exaggeration to houses, were torn out of a more ancient alluvion, and borne down for a quarter of a mile. One of the fragments moved was sixty paces in circumference.* The velocity of the water, in the first part of its course was thirty-three feet per second, which diminished to six feet before it reached

* This block was measured by Capt. B. Hall, R. N.

the Lake of Geneva, where it arrived in six hours and a half, the distance being forty-five miles.*

This flood left behind it, on the plains of Martigny, thousands of trees torn up by the roots, together with the ruins of buildings. Some of the houses in that town were filled with mud up to the second story. After expanding in the plain of Martigny, it entered the Rhone, and did no further damage; but some bodies of men, who had been drowned above Martigny, were afterwards found, at the distance of about thirty miles, floating on the farther side of the Lake of Geneva, near Vevey.

The waters, on escaping from the temporary lake, intermixed with mud and rock, swept along, for the first four miles, at the rate of above twenty miles an hour; and M. Escher, the engineer, calculated that the flood furnished 300,000 cubic feet of water every second — an efflux which is five times greater than that of the Rhine below Basle. Now, if part of the lake had not been gradually drained off, the flood would have been nearly double, approaching in volume to some of the largest rivers in Europe. It is evident, therefore, that, when we are speculating on the excavating force which a river may have exerted in any particular valley, the most important question is, not the volume of the existing stream, nor the present levels of its channel, nor even the nature of the rocks, but the probability of a succession of floods at some period since the time when the valley may have been first elevated above the sea.

For several months after the débâcle of 1818, the

* See an account of the inundation of the Val de Bagnes, in 1818, in Ed. Phil. Journ., vol. i. p. 187., drawn up from the Memoir of M. Escher, with a section, &c.

Dranse, having no settled channel, shifted its position continually from one side to the other of the valley, carrying away newly erected bridges, undermining houses, and continuing to be charged with as large a quantity of earthy matter as the fluid could hold in suspension. I visited this valley four months after the flood, and was witness to the sweeping away of a bridge, and the undermining of part of a house. The greater part of the ice-barrier was then standing, presenting vertical cliffs 150 feet high, like ravines in the lava-currents of Etna or Auvergne, where they are intersected by rivers.

Inundations, precisely similar, are recorded to have occurred at former periods in this district, and from the same cause. In 1595, for example, a lake burst, and the waters, descending with irresistible fury, destroyed the town of Martigny, where from sixty to eighty persons perished. In a similar flood, fifty years before, 140 persons were drowned.

Flood at Tivoli, 1826. — I shall conclude with one more example, derived from a land of classic recollections, the ancient Tibur, and which, like all the other inundations above alluded to, occurred within the present century. The younger Pliny, it will be remembered, describes a flood on the Anio, which destroyed woods, rocks, and houses, with the most sumptuous villas and works of art.* For four or five centuries consecutively, this “headlong stream,” as Horace truly called it, has often remained within its bounds, and then, after so long an interval of rest, has at different periods inundated its banks again, and widened its channel. The last of these catastrophes happened 15th Nov. 1826, after heavy rains, such as produced

* Lib. viii. Epist. 17.

the floods before alluded to in Scotland. The waters appear also to have been impeded by an artificial dike, by which they were separated into two parts, a short distance above Tivoli. They broke through this dike; and, leaving the left trench dry, precipitated themselves, with their whole weight, on the right side. Here they undermined, in the course of a few hours, a high cliff, and widened the river's channel about fifteen paces. On this height stood the church of St. Lucia, and about thirty-six houses of the town of Tivoli, which were all carried away, presenting, as they sank into the roaring flood, a terrific scene of destruction to the spectators on the opposite bank. As the foundations were gradually removed, each building, some of them edifices of considerable height, was first traversed with numerous rents, which soon widened into large fissures, until at length the roofs fell in with a crash, and then the walls sank into the river, and were hurled down the cataract below.*

The destroying agency of the flood came within two hundred yards of the precipice on which the beautiful temple of Vesta stands; but fortunately this precious relic of antiquity was spared, while the wreck of modern structures was hurled down the abyss. Vesta, it will be remembered, in the heathen mythology, personified the stability of the earth; and when the Samian astronomer, Aristarchus, first taught that the earth revolved on its axis, and round the sun, he was publicly accused of impiety, "for moving the everlasting Vesta from her place." Playfair observed, that when Hutton ascribed instability to the earth's

* When at Tivoli, in 1829, I received this account from eye-witnesses of the event.

surface, and represented the continents which we inhabit as the theatre of incessant change and movement, his antagonists, who regarded them as unalterable, assailed him in a similar manner with accusations founded on religious prejudices.* We might appeal to the excavating power of the Anio as corroborative of one of the most controverted parts of the Huttonian theory; and if the days of omens had not gone by, the geologists who now worship Vesta might regard the late catastrophe as portentous. We may, at least, recommend the modern votaries of the goddess to lose no time in making a pilgrimage to her shrine, for the next flood may not respect the temple.

* Illustr. of Hutt. Theory, § 3. p. 147.

CHAPTER III.

TRANSPORTATION OF SOLID MATTER BY ICE.

Carrying power of river-ice — Rocks annually conveyed into the St. Lawrence by its tributaries — Effects of the rise of the tide in the estuary of the St. Lawrence — Ground-ice ; its origin and transporting power — Glaciers — Theory of their downward movement — The moraine unstratified — Icebergs covered with mud and stones — Limits of glaciers and icebergs — Their effects on the bottom when they run aground — Packing of coast ice — Boulders drifted by ice on coast of Labrador — Blocks moved by ice in the Baltic — Submarine erratics laid dry by upheaval.

THE power of running-water to carry sand, gravel, and fragments of rock to considerable distances is greatly augmented in those regions where, during some part of the year, the frost is of sufficient intensity to convert the water, either at the surface or bottom of rivers, into ice.

This subject may be considered under three different heads : — first, the effect of surface-ice and ground-ice in enabling streams to remove gravel and stones to a distance ; secondly, the action of glaciers in the transport of boulders, and in the polishing and scratching of rocks ; thirdly, the floating off of glaciers charged with solid matter into the sea, and the drifting of icebergs and coast-ice.

River-ice. — Pebbles and small pieces of rock may be seen entangled in ice, and floating annually down

the Tay in Scotland, as far as the mouth of that river. Similar observations might doubtless be made respecting almost all the larger rivers of England and Scotland, but there seems reason to suspect that the principal transfer from place to place of pebbles and stones adhering to ice goes on unseen by us under water. For although the specific gravity of the compound mass may cause it to sink, it may still be very buoyant, and easily borne along by a feeble current. The ice, moreover, melts very slowly at the bottom of running streams in winter, as the water there is often nearly at the freezing point, as will be seen from what will be said in the sequel of ground-ice.

As we traverse Europe in the latitudes of Great Britain, we find the winters more severe, and the rivers more regularly frozen over. M. Lariviere relates that, being at Memel on the Baltic in 1821, when the ice of the river Niemen broke up, he saw a mass of ice thirty feet long which had descended the stream, and had been thrown ashore. In the middle of it was a triangular piece of granite, about a yard in diameter, resembling in composition the red granite of Finland.*

When rivers in the northern hemisphere flow from south to north, the ice first breaks up in the higher part of their course, and the flooded waters, bearing along large icy fragments, often arrive at parts of the stream which are still firmly frozen over. Great inundations are thus frequently occasioned by the obstructions thrown in the way of the descending waters, as was before noticed when I spoke of the Mackenzie in North America, and the Irtish, Oby, Yenesei, Lena, and other rivers of Siberia. (See p. 150.) A partial

* *Consid. sur les Blocs Errat.* 1829.

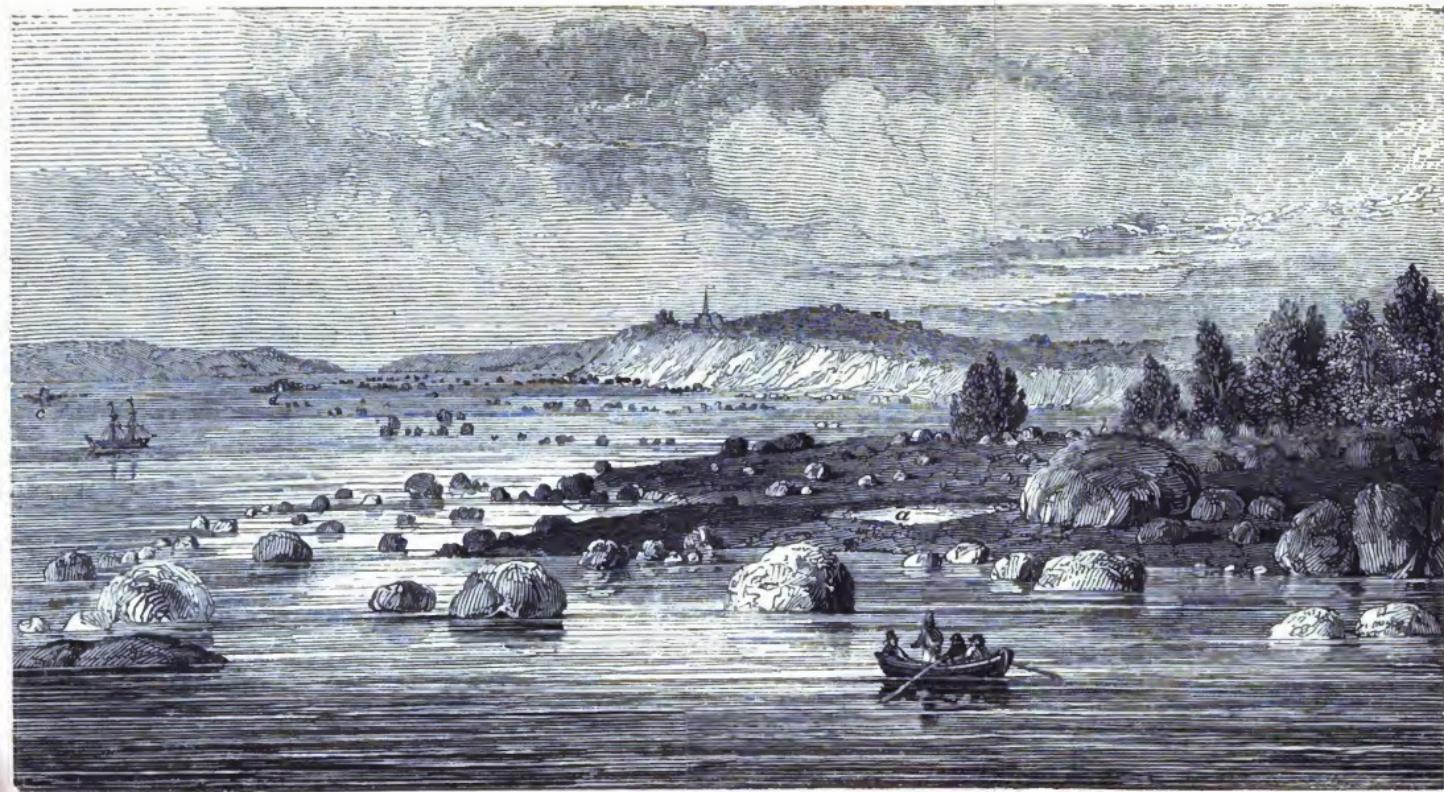
stoppage of this kind lately occurred (Jan. 31. 1840) in the Vistula, about a mile and a half above the city of Dantzig, where the river, choked up by packed ice, was made to take a new course over its right bank, so that it hollowed out in a few days a deep and broad channel, many leagues in length, through a tract of sand hills which were from 40 to 60 feet high.

In Canada, where the winter's cold is intense, in a latitude corresponding to that of central France, several tributaries of the St. Lawrence begin to thaw in their upper course, while they remain frozen over lower down, and thus large slabs of ice are set free and thrown upon the unbroken sheet of ice below. Then begins what is called the packing of the drifted fragments, that is to say, one slab is made to slide over another, until a vast pile is built up, and the whole being frozen together, is urged onwards by the force of the dammed up waters and drift ice. Thus propelled, it not only forces along boulders, but breaks off from cliffs, which border the rivers, huge pieces of projecting rock. By this means several buttresses of solid masonry, which, up to the year 1836, supported a wooden bridge on the St. Maurice, which falls into the St. Lawrence, near the town of Trois Rivières, lat. $46^{\circ} 20'$, were thrown down, and conveyed by the ice into the main river; and instances have occurred at Montreal of wharfs and stone-buildings, from 30 to 50 feet square, having been removed in a similar manner. We learn from Captain Bayfield that anchors laid down within high-water mark, to secure vessels hauled on shore for the winter, must be cut out of the ice on the approach of spring, or they would be carried away. In 1834, the Gulnare's bower anchor, weighing half a ton, was transported some yards by

the ice, and so firmly was it fixed, that the force of the moving ice broke a chain-cable suited for a 10-gun brig, and which had rode the Gulnare during the heaviest gales in the Gulf. Had not this anchor been cut out of the ice, it would have been carried into deep water and lost.*

The scene represented in the annexed plate (pl. 4.), from a drawing by Lieutenant Bowen, R.N., will enable the reader to comprehend the incessant changes which the transport of boulders produces annually on the low islands, shores, and bed of the St. Lawrence above Quebec. The fundamental rocks at Richelieu Rapid, situated in lat. 46° N., are limestone and slate, which are seen at low water to be covered with boulders of granite. These boulders owe their spheroidal form chiefly to weathering, or the action of frost, which causes the surface to exfoliate in concentric plates, so that all the more prominent angles are removed. At the point *a* is a cavity in the mud or sand of the beach, now filled with water, which was occupied during the preceding winter (1835) by the huge erratic *b*, a mass of granite, 70 tons' weight, found in the spring following (1836) at the distance of several feet from its former position. Many small islands are seen on the river, such as *c d*, which afford still more striking proofs of the carrying and propelling power of ice. These islets are never under water, yet every winter ice is thrown upon them in such abundance, that it *packs* to the height of 20, and even 30 feet, bringing with it a continual supply of large stones or boulders, and carrying away others; the greatest number being deposited, according to Lieutenant

* Capt. Bayfield, Geol. Soc. Proceedings, vol. ii. p. 228.



BOULDERS DRIFTED BY ICE ON SHORES OF THE ST. LAWRENCE,

View taken from N. E., in the Spring of 1836, at Richelieu Rapid, lat. 46. N.

Bowen, on the edge of deep water. On the island *d*, on the left of the accompanying view, a lighthouse is represented, consisting of a square wooden building, which having no other foundation than the boulders, requires to be taken down every winter, and rebuilt on the re-opening of the river.

These effects of frost, which are so striking on the St. Lawrence above Quebec, are by no means displayed on a smaller scale below that city, where the gulf rises and falls with the tide. On the contrary, it is in the estuary, between the latitudes 47° and 49° , that the greatest quantity of gravel and boulders of large dimensions are carried down annually towards the sea. Here the frost is so intense, that a dense sheet of ice is formed at low water, which, on the rise of the tide, is lifted up, broken, and thrown in heaps on the extensive shoals which border the estuary. When the tide recedes, this packed ice is exposed to a temperature sometimes 30° below zero, which freezes together all the loose pieces of ice, as well as the granitic and other boulders. The whole of these are often swept away by a high tide, or when the river is swollen by the melting of the snow in spring. One huge block of granite, 15 feet long by 10 feet both in width and height, and estimated to contain 1500 cubic feet, was conveyed in this manner to some distance in the year 1837, its previous position being well known, as up to that time it had been used by Captain Bayfield as a mark for the surveying station.

Ground-ice. — When a current of cold air passes over the surface of a lake or stream it abstracts from it a quantity of heat, and the specific gravity of the water being thereby increased, the cooled portion sinks. This circulation may continue until the whole body of

fluid has been cooled down to the temperature of 40° F., after which, if the cold increase, the vertical movement ceases, the water which is uppermost expands and floats over the heavier fluid below, and when it has attained a temperature of 32° Fahr. it sets into a sheet of ice. It should seem therefore impossible, according to this law of congelation, that ice should ever form at the bottom of a river; and yet such is the fact, and many speculations have been hazarded to account for so singular a phenomenon. M. Arago is of opinion that the mechanical action of a running stream produces a circulation by which the entire body of water is mixed up together and cooled alike, and the whole being thus reduced to the freezing point, ice begins to form at the bottom for two reasons, first, because there is less motion there, and secondly, because the water is in contact with solid rock or pebbles which have a cold surface.* Whatever explanation we adopt, there is no doubt of the fact, that in countries where the intensity and duration of the cold is great, rivers and torrents acquire an increase of carrying power by the formation of what is called ground-ice. Even in the Thames we learn from Dr. Plot that pieces of this kind of ice, having gravel frozen on to their under side, rise up from the bottom in winter, and float on the surface. In the Siberian rivers, Weitz describes large stones as having been brought up from the river's bed in the same manner, and made to float.†

Glaciers. — In the valleys of all countries bordering the polar circles, and in the higher mountains in temperate latitudes, the snow accumulates in winter, and

* M. Arago, *Annuaire, &c.* 1833; and Rev. J. Farquharson, *Phil. Trans.* 1835, p. 329.

† *Journ. of Roy. Geograph. Soc.* vol. vi. p. 416.

being afterwards partially converted into ice, constitutes what are called glaciers. These in the arctic and antarctic regions descend the valleys gradually till they reach the ocean, where they are floated off in the shape of icebergs, but in lower latitudes, as in the Alps, they descend far below the level of perpetual snow, and there melting, give rise to torrents.

"It has been a generally received opinion," says M. Agassiz, "from the time of Saussure, that the downward movement of a glacier is nothing more than a slipping upon itself occasioned by its own weight; but there are many reasons for doubting the accuracy of this explanation. The motion appears to be much more properly ascribed to the expansion of the ice resulting from the congelation of the water which has filtered into it and penetrated its cavities, for the mass of each glacier is traversed by innumerable fissures which descend to various depths, and are in great part filled with rain water, together with that produced by the melting of the surface-ice. This water being always extremely cold, is made to freeze by the least sinking of the temperature, and tends to dilate the glacier in every direction; but as the mass of ice is restrained on two sides by the flanks of the valley, and on a third by the weight of the ice above, the whole act of dilatation, aided by that of gravitation, tends to urge the glacier down the declivity, or to the only side which offers a free passage." *

But Mr. R. Mallet, in a late memoir on this subject, ascribes the progressive movement of glaciers, which sometimes advance in the Alps as much as twenty-five feet in a year, to the hydrostatic pressure of the

* Agassiz, Jamieson's Ed. New Phil. Journ., No. liv. p. 383. ;

water which flows at the bottom, and fills rents in the mass. If any obstruction, such as the falling in of ice, stop for a time the free passage of the water flowing below, the accumulated fluid would rend and lift up huge masses, as happened in the winter of 1814-15. At that period the Arveron, a torrent flowing at the bottom of the Mer de Glace, was partly frozen, and partly dammed up by falling masses of ice, so that it could no longer discharge itself at its usual opening, that green arch in which its icy tunnel terminates. The water accumulated, therefore, until it forced itself a new opening 700 feet above the former one, the pressure being so great that for several months huge fragments of ice were precipitated from the glacier.*

Those parts of the Swiss Alps which are more than 8000 feet high are covered with perpetual snow, but the glaciers in the valley of Chamouni descend 4000 feet below this limit, or no less than 12,000 feet below the summit of Mont Blanc : where they reach a district about 3000 feet above the level of the sea in lat. 46°. There they appear, in the heat of summer, in the midst of green forests, and luxuriant pastures, assuming the most fantastic and picturesque shapes, and often terminating upwards in numerous peaks and pinnacles of white ice. According to Saussure, their mean vertical thickness is from 80 to 100 feet, but it amounts in some chasms even to 600 feet.†

The surface of the moving glacier is loaded with sand and large stones derived from boundary rocks, which are precipitous, and occasionally overhanging, and of which pieces are detached by frost or ava-

* Mallet, *Seventh Report of Brit. Assoc.* p. 64. 1897.

† *Voy. dans les Alpes*, tom. i. p. 440.

lanches, or broken off by the friction of the moving ice itself, or washed down by torrents. Such materials are generally arranged in long ridges or mounds, sometimes thirty or forty feet high. They are often two, three, or even more in number, like so many lines of intrenchment, and consist of the debris which have been brought in by lateral glaciers. The whole accumulation is called in Switzerland "the moraine," which is slowly conveyed to inferior valleys, and left, where the snow and ice melt, upon the plain. All sand and fragments of soft stone which fall through fissures and reach the bottom of the glaciers, or which are interposed between the glacier and the steep sides of the valley, are pushed along and ground into mud, while the larger and harder fragments have their angles worn off. The fundamental and boundary rocks are also smoothed and polished, and often scored with parallel furrows, or with lines and scratches produced by hard minerals, such as crystals of quartz, which act like the diamond upon glass.*

The moraine of the glacier, observes Charpentier, is entirely devoid of stratification, for there has been no sorting of the materials, as in the case of sand, mud, and pebbles, when deposited by running water. The ice transports indifferently, and to the same spots, the heaviest blocks and the finest particles, mingling all together, and leaving them in one confused and promiscuous heap wherever it melts.†

Icebergs. — In countries situated in high northern latitudes, like Spitzbergen, between 70° and 80° N.,

* Agassiz, Jam. Ed. New Phil. Journ. No. liv. p. 388.

† Charpentier, Ann. des Mines, tom. viii.; see also Papers by MM. Venetz and Agassiz.

glaciers, loaded with mud and rock, descend to the sea, and there huge fragments of them float off and become icebergs. Scoresby counted 500 of these bergs drifting along in latitudes 69° and 70° N., which rose above the surface from the height of 100 to 200 feet, and measured from a few yards to a mile in circumference.* Many of them were loaded with beds of earth and rock of such thickness, that the weight was conjectured to be from 50,000 to 100,000 tons. Specimens of the rocks were obtained, and among them were granite, gneiss, mica-schist, clay-slate, granular felspar, and greenstone. Such bergs must be of great magnitude; because the mass of ice below the level of the water is about eight times greater than that above. Wherever they are dissolved, it is evident that the "moraine" will fall to the bottom of the sea. In this manner may submarine valleys, mountains, and platforms become strewed over with gravel, sand, mud, and scattered blocks of foreign rock, of a nature perfectly dissimilar from all in the vicinity, and which may have been transported across unfathomable abysses. If the bergs happen to melt in still water, so that the earthy and stony materials may fall tranquilly to the bottom, the deposit will probably be unstratified, like the terminal moraine of a glacier; but whenever the materials are under the influence of a current of water as they fall, they will be sorted and arranged according to their relative weight and size, and therefore more or less perfectly stratified.

In a former chapter it was stated, that some ice islands have been known to drift from Baffin's Bay to

* Voyage in 1822, p. 233.

the Azores, and from the South Pole to the immediate neighbourhood of the Cape of Good Hope, so that the area over which the effects of moving ice may be experienced, comprehends a large portion of the globe.

We learn from Von Buch that the most southern point on the continent of Europe at which a glacier comes down to the sea is in Norway, in lat. 67° N.* But Mr. Darwin has shown, that they extend to the sea, in South America, in latitudes more than 20° nearer the equator than in Europe; as for example in Chili, where, in the Gulf of Penas, lat. $46^{\circ} 40'$ S., or the latitude of central France; and in Sir George Eyre's Sound, in the latitude of Paris, they give origin to icebergs, which were seen in 1834 carrying angular pieces of granite, and stranding them in fiords, where the shores were composed of clay-slate.† In the island of Georgia, in lat. 54° S., where the perpetual snow descends to the sea-coast, glaciers have been observed to generate icebergs covered with mud and stones.

In a late voyage of discovery made in the antarctic regions in 1839, a dark-coloured angular mass of rock was seen imbedded in an iceberg, drifting along in mid ocean in lat. 61° S. That part of the rock which was visible was about 12 feet in height, and from 5 to 6 in width, but the dark colour of the surrounding ice indicated that much more of the stone was concealed. A sketch made by Mr. Macnab, when the vessel was within a quarter of a mile of it, is now published.‡ This iceberg, one of many observed at sea on the same

* Travels in Norway. † Darwin's Journal, p. 283.

‡ Journ. of Roy. Geograph. Soc., vol. ix. p. 526.

day, was between 250 and 300 feet high, and was no less than 1400 miles from any certainly known land. It is exceedingly improbable, says Mr. Darwin, in his notice on this phenomenon, that any land will hereafter be discovered within 100 miles of the spot, and it must be remembered that the erratic was still firmly fixed in ice, and may have sailed for many a league farther before it dropped to the bottom.*

In the account given by Messrs. Dease and Simpson, of their recent arctic discoveries, we learn that in lat. 71° N., long. 156° W., they found "a long low spit, named Point Barrow, composed of gravel and coarse sand, in some parts more than a quarter of a mile broad, which the pressure of the ice had forced up into numerous mounds, that, viewed from a distance, assumed the appearance of huge boulder rocks." †

This fact is important, as showing how masses of drift ice, when stranding on submarine banks, may exert a lateral pressure capable of bending and dislocating any yielding strata of gravel, sand, or mud. The banks on which icebergs occasionally run aground between Baffin's Bay and Newfoundland, are many hundred feet under water, and the force with which they are struck will depend not so much on the velocity as the momentum of the floating ice-islands. The same berg is often carried away by a change of wind, and then driven back again upon the same bank, or it is made to rise and fall by the waves of the ocean, so that it may alternately strike the bottom with its whole weight, and then be lifted up again, until it has deranged the superficial beds over

* Journ. of Roy. Geograph. Soc. vol. ix. p. 529.

† Ibid. vol. viii. p. 221.

a wide area. In this manner the geologist may account, perhaps, for the circumstance that in Scandinavia, Scotland, and other countries where erratics are met with, the beds of sand, loam, and gravel are often vertical, bent, and contorted into the most complicated folds, while the underlying strata, although composed of equally pliant materials, are horizontal. There can also be little doubt that icebergs must often break off the peaks and projecting points of submarine mountains, and must grate upon and polish their surface, furrowing or scratching them in precisely the same way as we have seen that glaciers act on the solid rocks over which they are propelled.

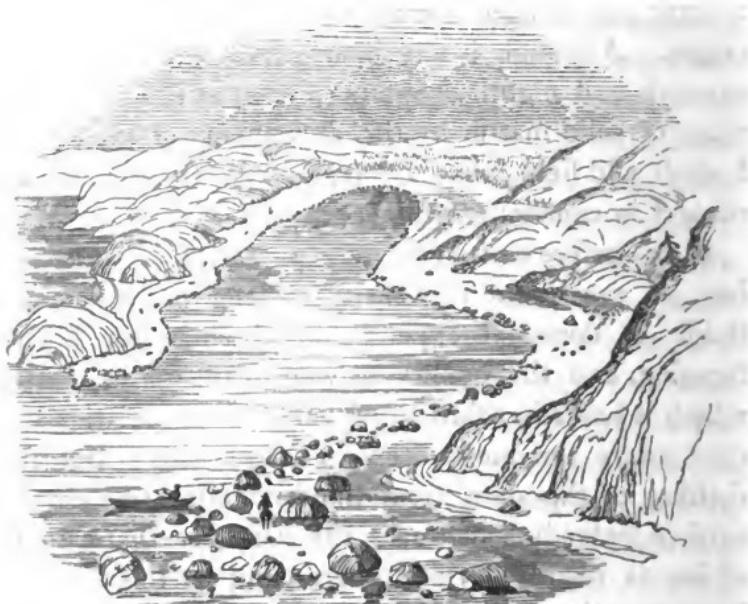
To conclude ; it appears that large stones, mud, and gravel, are carried down by the ice of rivers, estuaries, and glaciers, into the sea, where the tides and currents of the ocean, aided by the wind, cause them to drift for hundreds of miles from the place of their origin. Although it will belong more properly to the seventh and eighth chapters to treat of the transportation of solid matter by the movements of the ocean, I shall add here what I have further to say on this subject in connection with ice.

It was before stated (see note, p. 168.) that sea-water has no maximum of density so long as it remains fluid. It does not expand like fresh water before freezing, and this quality, as well as the saline matter which it holds in solution, prevents its congelation except where the most intense cold prevails. But the drifting of the snow from the land often renders the surface water brackish near the coast, so that a sheet of ice is readily formed there, and by this means a large quantity of gravel is frequently conveyed from place to place, and heavy boulders also, when the coast

ice is packed into dense masses. Both the large and small stones thus conveyed, usually travel in one direction like shingle-beaches, and this was observed to take place on the coast of Labrador and Gulf of St. Lawrence, between the latitudes 50° and 60° N., by Capt. Bayfield during his late survey. The line of coast alluded to is strewed over for a distance of 700 miles with ice-borne boulders, often 6 feet in diameter, which are for the most part on their way from north to south, or in the direction of the prevailing current. Some points on this coast have been observed to be occasionally deserted, and then again at another season thickly bestrewed with erratics.

The accompanying drawing (fig. 13.), for which I am indebted to Lieut. Bowen, R.N., represents the

Fig. 13.



Boulders, chiefly of granite, stranded by ice on the coast of Labrador, between lat. 50° and 60° N. (Lieut. Bowen, R. N.)

ordinary appearance of the Labrador coast, between the latitudes of 50° and 60° N. Countless blocks, chiefly granitic, and of various sizes, are seen lying between high and low water mark. Capt. Bayfield saw similar masses carried by ice through the Straits of Belle Isle, between Newfoundland and the American continent, which he conceives may have travelled in the course of years from Baffin's Bay, a distance which may be compared in our hemisphere to the drifting of erratics from Lapland and Iceland as far south as Germany, France, and England.

It may be asked, in what manner have these blocks been originally detached? We may answer that some have fallen from precipitous cliffs, others have been lifted up from the bottom of the sea, adhering by their tops to the ice, while others have been brought down by rivers and glaciers.

The erratics of North America are sometimes angular, but most of them have been rounded either by friction or decomposition. The granite of Canada, as before remarked (p. 372.), has a tendency to concentric exfoliation, and scales off in spheroidal coats when exposed to the spray of the sea during severe frosts. The range of the thermometer in that country usually exceeds, in the course of the year, 100° and sometimes 120° F.; and, to prevent the granite used in the buildings of Quebec from peeling off in winter, it is necessary to oil and paint the squared stones.

In parts of the Baltic, such as the Gulf of Bothnia, where the quantity of salt in the water amounts in general to one fourth only of that in the ocean, the entire surface freezes over in winter to the depth of 5 or 6 feet. Stones are thus frozen in, and afterwards lifted up about 3 feet perpendicularly on the melting of the snow in summer, and then carried by

floating ice-islands to great distances. Professor Von Baer states, in a communication on this subject to the Academy of St. Petersburg, that a block of granite, weighing a million of pounds, was carried by ice during the winter of 1837-8 from Finland to the island of Hochland, and two other huge blocks were transported about the years 1806 and 1814 by packed ice on the south coast of Finland, according to the testimony of the pilots and inhabitants, one block having travelled about a quarter of a mile, and lying about 18 feet above the level of the sea.*

It is well known to all geologists that many enormous masses of gneiss and other rocks are scattered over the low lands bordering the Baltic, which may have been laid dry by that slow upheaval and dessication of the bottom of the sea, which is now ascertained to be going on in Sweden and the Gulf of Bothnia. This upward movement may, in the course of ages, have worked so entire a change in the physical geography of these countries, that it is scarcely possible to speculate on the course which drift ice may formerly have taken in northern Europe, unless we are guided by geological data. In those parts of Canada and Labrador where boulders are most frequent on the sea-beach, they are said to be equally numerous in the interior, being seen in as great abundance as the stumps of trees wherever the forests have been partially cleared away. This phenomenon need not be attributed, as some have proposed, to the passage of a flood over the land, but rather to a change of level, like that observed in Scandinavia, which is slowly converting the bed of the ancient ocean, long the receptacle of icebergs, into a part of the American continent.

* Jam. Ed. New Phil. Journ. No. xlviij. p. 439.

CHAPTER IV.

PHENOMENA OF SPRINGS.

Origin of springs — Bored wells — Distinct causes by which mineral and thermal waters may be raised to the surface — Their connection with volcanic agency — Calcareous springs — Travertin of the Elsa — Baths of San Vignone and of San Filippo, near Radicofani — Spheroidal structure in travertin, as in English magnesian limestone — Bulicami of Viterbo — Lake of the Solfatara, near Rome — Travertin at Cascade of Tivoli — Gypseous, siliceous, and ferruginous springs — Brine springs — Carbonated springs — Disintegration of granite in Auvergne — Petroleum springs — Pitch lake of Trinidad.

Origin of springs. — THE action of running water on the land having been considered, we may next turn our attention to what may be termed “the subterranean drainage,” or the phenomena of springs. Every one is familiar with the fact, that certain porous soils, such as loose sand and gravel, absorb water with rapidity ; and that the ground composed of them soon dries up after heavy showers. If a well be sunk in such soils, we often penetrate to considerable depths before we meet with water; but this is usually found on our approaching the lower parts of the formation, where it rests on some impervious bed; for here the water, unable to make its way downwards in a direct line, accumulates as in a reservoir, and is ready to ooze out into any opening which may be made, in the same

manner as we see the salt water flow into, and fill, any hollow which we dig in the sands of the shore at low tide.

The facility with which water can percolate loose and gravelly soils is clearly illustrated by the effect of the tides in the Thames between Richmond and London. The river, in this part of its course, flows through a bed of gravel overlying clay, and the porous superstratum is alternately saturated by the water of the Thames as the tide rises, and then drained again to the distance of several hundred feet from the banks when the tide falls, so that the wells in this tract regularly ebb and flow.

If the transmission of water through a porous medium be so rapid, we cannot be surprised that springs should be thrown out on the side of a hill, where the upper set of strata consist of chalk, sand, or other permeable substances, while the subjacent are composed of clay or other retentive soils. The only difficulty, indeed, is to explain why the water does not ooze out every where along the line of junction of the two formations, so as to form one continuous land-soak, instead of a few springs only, and these far distant from each other. The principal cause of this concentration of the waters at a few points is, first, the frequency of rents and fissures, which act as natural drains; secondly, the existence of inequalities in the upper surface of the impermeable stratum, which lead the water, as valleys do on the external surface of a country, into certain low levels and channels.

That the generality of springs owe their supply to the atmosphere is evident from this, that they become languid, or entirely cease to flow, after long droughts, and are again replenished after a continuance of rain.

Many of them are probably indebted for the constancy and uniformity of their volume to the great extent of the subterranean reservoirs with which they communicate, and the time required for these to empty themselves by percolation. Such a gradual and regulated discharge is exhibited, though in a less perfect degree, in every great lake which is not sensibly affected in its level by sudden showers, but only slightly raised; so that its channel of efflux, instead of being swollen suddenly like the bed of a torrent, is enabled to carry off the surplus water gradually.

Much light has been thrown, of late years, on the theory of springs, by the boring of what are called by the French "Artesian wells," because the method has long been known and practised in Artois; and it is now demonstrated that there are sheets, and, in some places, currents of fresh water, at various depths in the earth. The instrument employed in excavating these wells is a large auger, and the cavity bored is usually from three to four inches in diameter. If a hard rock is met with, it is first triturated by an iron rod, and the materials, being thus reduced to small fragments or powder, are readily extracted. To hinder the sides of the well from falling in, as also to prevent the spreading of the ascending water in the surrounding soil, a jointed pipe is introduced, formed of wood in Artois, but in other countries more commonly of metal. It frequently happens that, after passing through hundreds of feet of retentive soils, a water-bearing stratum is at length pierced, when the fluid immediately ascends to the surface and flows over. The first rush of the water up the tube is often violent, so that for a time the water plays like a fountain, and then, sinking, continues to flow over tranquilly, or sometimes remains sta-

tionary at a certain depth below the orifice of the well. This spouting of the water in the first instance is probably owing to the disengagement of air and carbonic acid gas, for both of these have been seen to bubble up with the water.*

At Sheerness, at the mouth of the Thames, a well was bored on a low tongue of land near the sea, through 300 feet of the blue clay of London, below which a bed of sand and pebbles was entered, belonging, doubtless, to the plastic clay formation : when this stratum was pierced, the water burst up with impetuosity, and filled the well. By another perforation at the same place, the water was found at the depth of 328 feet, below the surface clay ; it first rose rapidly to the height of 189 feet, and then, in the course of a few hours, ascended to an elevation of eight feet above the level of the ground. In 1824 a well was dug at Fulham, near the Thames, at the Bishop of London's, to the depth of 317 feet, which, after traversing the tertiary strata, was continued through 67 feet of chalk. The water immediately rose to the surface, and the discharge was above 50 gallons per minute. In the garden of the Horticultural Society at Chiswick, the borings passed through 19 feet of gravel, $24\frac{1}{2}$ feet of clay and loam, and $67\frac{1}{2}$ feet of chalk, and the water then rose to the surface from a depth of 329 feet.† At the Duke of Northumberland's, above Chiswick, the borings were carried to the extraordinary depth of 620 feet, so as to enter the chalk, when a considerable volume of water was obtained, which rose four feet above the surface of the ground. In a well of Mr. Brooks, at

* Consult Héricart de Thury's work on "Puits Forés."

† Sabine, Journ. of Sci. No. xxxiii. p. 72. 1824.

Hammersmith, the rush of water from a depth of 360 feet was so great, as to inundate several buildings and do considerable damage; and at Tooting, a sufficient stream was obtained to turn a wheel, and raise the water to the upper stories of the houses.* In the last of three wells bored through the chalk, at Tours, to the depth of several hundred feet, the water rose 32 feet above the level of the soil, and the discharge amounted to 300 cubic yards of water every twenty-four hours.†

Excavations have been made in the same way to the depth of 800, and even 1200 feet, in France (the latter at Toulouse), and without success.‡ By way of experiment, they are now sinking a well at Paris, the boring of which had reached, in November, 1839, a depth of more than 1600 English feet, and which it is determined to continue to the depth of more than 2000 feet, if overflowing water be not found sooner. It is presumed that the water issuing from so great a depth will possess a temperature of between 93° and 95° F., and the temperature has increased at present at the rate of 1° 8' F. for 101 English feet. Mr. Briggs, the British consul in Egypt, obtained water between Cairo and Suez, in a calcareous sand, at the depth of thirty feet; but it did not rise in the well.§ But other borings in the same desert, of variable depth, between 50 and 300 feet, and which passed through alternations of sand, clay, and siliceous rock, yielded water at the surface.|| The geological structure of

* Héricart de Thury, p. 49.

† Bull. de la Soc. Géol. de France, tom. iii. p. 194.

‡ Id. tom. ii. p. 272.

§ Boué, Résumé des Prog. de la Géol. en 1832, p. 184.

|| Seventh Rep. Brit. Ass. 1837, p. 66.

the Sahara is supposed, by M. Rozet, to favour the prospect of a supply of water from Artesian wells, as the parched sands on the outskirts of the desert rest on a substratum of argillaceous marl.*

The rise and overflow of the water in these wells is generally referred, and apparently with reason, to the same principle as the play of an artificial fountain. Let the porous stratum, or set of strata, $\alpha\alpha$, rest on the impermeable rock d , and be covered by another mass of an impermeable nature. The whole mass $\alpha\alpha$ may easily, in such a position, become saturated with water, which may descend from its higher and exposed parts—a hilly region to which clouds are attracted,

Fig. 14.



and where rain falls in abundance. Suppose that at some point, as at b , an opening be made, which gives a free passage upwards to the waters confined in $\alpha\alpha$, at so low a level that they are subjected to the pressure of a considerable column of water collected in the more elevated portion of the same stratum. The water will then rush out, just as the liquid from a large barrel which is tapped, and it will rise to a height corresponding to the level of its point of departure, or, rather, to a height which balances the pressure previously exerted by the confined waters against the roof and sides of the stratum or reservoir

* Bull. de la Soc. Géol. de France, tom. ii. p. 364.

a a. In like manner, if there happen to be a natural fissure *c*, a spring will be produced at the surface on precisely the same principle.

Among the causes of the failure of Artesian wells, we may mention those numerous rents and faults which abound in some rocks, and the deep ravines and valleys by which many countries are traversed; for, when these natural lines of drainage exist, there remains a small quantity only of water to escape by artificial issues. We are also liable to be baffled by the great thickness either of porous or impervious strata, or by the dip of the beds, which may carry off the waters from adjoining high lands to some trough in an opposite direction, as when the borings are made at the foot of an escarpment where the strata incline inwards, or in a direction opposite to the face of the cliffs.

The mere distance of hills or mountains need not discourage us from making trials; for the waters which fall on these higher lands readily penetrate to great depths through highly inclined or vertical strata, or through the fissures of shattered rocks, and after flowing for a great distance, must often re-ascend and be brought up again by other fissures, so as to approach the surface in the lower country. Here they may be concealed beneath a covering of undisturbed horizontal beds, which it may be necessary to pierce in order to reach them. It should be remembered, that the course of waters flowing under ground bears but a remote resemblance to that of rivers on the surface, there being, in the one case, a constant descent from a higher to a lower level from the source of the stream to the sea; whereas, in the other, the water may at one time

sink far below the level of the ocean, and afterwards rise again high above it.

Among other curious facts ascertained by aid of the borer, it is proved that in strata of different ages and compositions, there are often open passages by which the subterranean waters circulate. Thus at St. Ouen, in France, five distinct sheets of water were intersected in a well, and from each of these a supply obtained. In the third water-bearing stratum, at the depth of 150 feet, a cavity was found in which the borer fell suddenly about a foot, and thence the water ascended in great volume.* The same falling of the instrument, as in a hollow space, has been remarked in England and other countries. At Tours, in 1830, a well was perforated quite through the chalk, when the water suddenly brought up, from a depth of 364 feet, a great quantity of fine sand, with much vegetable matter and shells. Branches of a thorn several inches long, much blackened by their stay in the water, were recognized, as also the stems of marsh plants, and some of their roots, which were still white, together with the seeds of the same, in a state of preservation, which showed that they had not remained more than three or four months in the water. Among the seeds were those of the marsh-plant *Galium uliginosum*; and among the shells, a freshwater species (*Planorbis marginatus*), and some land species, as *Helix rotundata* and *H. striata*. M. Dujardin, who, with others, observed this phenomenon, supposes that the waters had flowed from some valleys of Auvergne or the Vivarais since the preceding autumn. †

* H. de Thury, p. 295.

† Bull. de la Soc. Géol. de France, tom. i. p. 93.

An analogous phenomenon is recorded at Riemke, near Bochum in Westphalia, where the water of an Artesian well brought up, from a depth of 156 feet, several small fish, three or four inches long, the nearest streams in the country being at the distance of some leagues.*

In both cases it is evident that water had penetrated to great depths, not simply by filtering through a porous mass, for then it would have left behind the shells, fish, and fragments of plants, but by flowing through some open channels in the earth. Such examples may suggest the idea that the leaky beds of rivers are often the feeders of springs.

MINERAL AND THERMAL SPRINGS.

Almost all springs, even those which we consider the purest, are impregnated with some foreign ingredients, which, being in a state of chemical solution, are so intimately blended with the water, as not to affect its clearness, while they render it, in general, more agreeable to our taste, and more nutritious than simple rain-water. But the springs called mineral contain an unusual abundance of earthy matter in solution, and the substances with which they are impregnated correspond remarkably with those evolved in a gaseous form by volcanos. Many of these springs are thermal, and they rise up through all kinds of rock; as, for example, through granite, gneiss, limestone, or lava, but are most frequent in volcanic regions, or where violent earthquakes have occurred at eras comparatively modern.

The water given out by hot springs is generally

* Bull. de la Soc. Géol. de France, tom. ii. p. 248

more voluminous and less variable in quantity at different seasons than that proceeding from any others. In many volcanic regions, jets of steam, called by the Italians "stufas," issue from fissures, at a temperature high above the boiling point, as in the neighbourhood of Naples, and in the Lipari Isles, and are disengaged unceasingly for ages. Now, if such columns of steam, which are often mixed with other gases, should be condensed before reaching the surface by coming in contact with strata filled with cold water, they may give rise to thermal and mineral springs of every degree of temperature. It is, indeed, by this means only, and not by hydrostatic pressure, that we can account for the rise of such bodies of water from great depths; nor can we hesitate to admit the adequacy of the cause, if we suppose the expansion of the same elastic fluids to be sufficient to raise columns of lava to the lofty summits of volcanic mountains. Several gases, the carbonic acid in particular, are disengaged in a free state from the soil in many districts, especially in the regions of active or extinct volcanos; and the same are found more or less intimately combined with the waters of all mineral springs, both cold and thermal. Dr. Daubeny and other writers have remarked, not only that these springs are most abundant in volcanic regions, but that when remote from them, their site usually coincides with the position of some great derangement in the strata; a fault, for example, or great fissure, indicating that a channel of communication has been opened with the interior of the earth at some former period of local convulsion. It is also ascertained that at great heights in the Pyrenees and Himalaya mountains hot springs burst out from granitic rocks, and they are abundant in the Alps also,

these chains having all been disturbed and dislocated at times comparatively modern, as can be shown by independent geological evidence.

The small area of volcanic regions may appear, at first view, an objection to some of the views above set forth, but not so when we include earthquakes among the effects of igneous agency. A large proportion of the land hitherto explored by geologists can be shown to have been rent or shaken by subterranean movements since the oldest tertiary strata were formed. It will also be seen, in the sequel, that new springs have burst out, and others have had the volume of their waters augmented, and their temperature suddenly raised after earthquakes, so that the description of these springs might almost with equal propriety have been given under the head of "igneous causes," as they are agents of a mixed nature, being at once igneous and aqueous.

But how, it will be asked, can the regions of volcanic heat send forth such inexhaustible supplies of water? The difficulty of solving this problem would, in truth, be insurmountable, if we believed that all the atmospheric waters found their way into the basin of the ocean; but in boring near the shore, we often meet with streams of fresh water at the depth of several hundred feet below the sea level; and these probably descend, in many cases, far beneath the bottom of the sea, when not artificially intercepted in their course. Yet, how much greater may be the quantity of salt water which sinks beneath the floor of the ocean, through the porous strata of which it is often composed, or through fissures rent in it by earthquakes. After penetrating to a considerable depth, this water may encounter a heat of sufficient intensity to convert

it into vapour, even under the high pressure to which it would then be subjected. This heat would probably be nearest the surface in volcanic countries, and farthest from it in those districts which have been longest free from eruptions or earthquakes ; but to pursue this inquiry farther would lead us to anticipate many topics belonging to another division of our subject.

It would follow from the views above explained, that there must be a two-fold circulation of terrestrial waters ; one caused by solar heat, and the other by heat generated in the interior of our planet. We know that the land would be unfit for vegetation, if deprived of the waters raised into the atmosphere by the sun ; but it is also true that mineral springs are powerful instruments in rendering the surface subservient to the support of animal and vegetable life. Their heat is said to promote the development of the aquatic tribes in many parts of the ocean, and the substances which they carry up from the bowels of the earth to the habitable surface, are of a nature and in a form which adapts them peculiarly for the nutrition of animals and plants.

As these springs derive their chief importance to the geologist from the quantity and quality of the earthy materials which, like volcanos, they convey from below upwards, they may properly be considered in reference to the ingredients which they hold in solution. These consist of a great variety of substances ; but the most predominant are, carbonate of lime, carbonic and sulphuric acids, iron, silica, magnesia, alumine, and salt, besides petroleum, or liquid bitumen, and its various modifications, such as mineral pitch, naphtha, and asphaltum.

Calcareous springs.—Our first attention is naturally directed to springs which are highly charged with calcareous matter, for these produce a variety of phenomena of much interest in geology. It is known that rain-water has the property of dissolving the calcareous rocks over which it flows, and thus, in the smallest ponds and rivulets, matter is often supplied for the earthy secretions of testacea, and for the growth of certain plants on which they feed. But many springs hold so much carbonic acid in solution, that they are enabled to dissolve a much larger quantity of calcareous matter than rain-water; and when the acid is dissipated in the atmosphere, the mineral ingredients are thrown down, in the form of tufa or travertin.*

Auvergne.—Calcareous springs, although most abundant in limestone districts, are by no means confined to them, but flow out indiscriminately from all rock formations. In Central France, a district where the primary rocks are unusually destitute of limestone, springs copiously charged with carbonate of lime rise up through the granite and gneiss. Some of these are thermal, and probably derive their origin from the deep source of volcanic heat, once so active in that region. One of these springs, at the northern base of the hill upon which Clermont is built, issues from volcanic peperino, which rests on granite. It has formed, by its incrustations, an elevated mound of travertin, or white concretionary limestone, 240 feet in length, and, at its termination, sixteen feet high and twelve wide. Another incrusting spring in the same department, situated at Chaluzet, near Pont Gibaud, rises in a

* The more loose and porous rock, usually containing incrusted plants and other substances, is called *tufa*; the more compact, *travertin*. See Glossary, 'Tufa,' 'Travertin,' end of Vol. III.

gneiss country, at the foot of a regular volcanic cone, at least twenty miles from any calcareous rock. Some masses of tufaceous deposit, produced by this spring, have an oolitic texture.

Valley of the Elsa.—If we pass from the volcanic district of France to that which skirts the Apennines in the Italian peninsula, we meet with innumerable springs which have precipitated so much calcareous matter, that the whole ground in some parts of Tuscany is coated over with tufa and travertin, and sounds hollow beneath the foot.

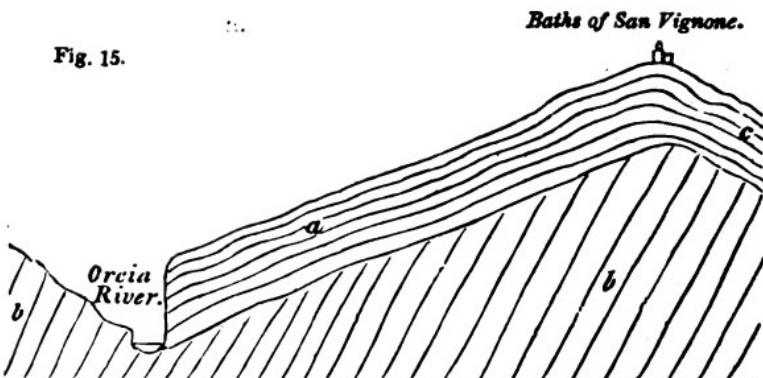
In other places in the same country, compact rocks are seen descending the slanting sides of hills, very much in the manner of lava currents, except that they are of a white colour, and terminate abruptly when they reach the course of a river. These consist of a calcareous precipitate from springs, some of which are still flowing, while others have disappeared or changed their position. Such masses are frequent on the slope of the hills which bound the valley of the Elsa, one of the tributaries of the Arno, which flows near Colle, through a valley several hundred feet deep, shaped out of a lacustrine formation, containing fossil shells of existing species. The travertin is unconformable to the lacustrine beds, and its inclination accords with the slope of the sides of the valley.

One of the finest examples which I saw, was at the Molino delle Caldane, near Colle.

The Sena, and several other small rivulets which feed the Elsa, have the property of lapidifying wood and herbs; and, in the bed of the Elsa itself, aquatic plants, such as Charæ, which absorb large quantities of carbonate of lime, are very abundant. Carbonic acid is also seen in the same valley, bubbling up from many

springs, where no precipitate of tufa is observable. Targioni, who in his travels has mentioned a great number of mineral waters in Tuscany, found no difference between the deposits of cold and thermal springs. They issue sometimes from the older Apennine limestone, shale, and sandstone, while, in other places, they flow from more modern deposits; but even in the latter case, their source may probably be in or below the older series of strata.

Baths of San Vignone.—Those persons who have merely seen the action of petrifying waters in our own country, will not easily form an adequate conception of the scale on which the same process is exhibited in those regions which lie nearer to the active centres of volcanic disturbance. One of the most striking examples of the rapid precipitation of carbonate of lime from thermal waters occurs in the hill of San Vignone in Tuscany, at a short distance from Radihofani, and only a few hundred yards from the high road between Sienna and Rome. The spring issues from near the summit of a rocky hill, about 100 feet in height. The top of the hill is flat, and stretches in a gently inclined platform to the foot of Mount Amiata, a lofty eminence, which consists in great part of volcanic products. The fundamental rock, from which the spring issues, is a black slate, with serpentine (*bb*, Fig. 15.), belonging to the older Apennine formation. The water is hot, has a strong taste, and, when not in very small quantity, is of a bright green colour. So rapid is the deposition near the source, that in the bottom of a conduit-pipe for carrying off the water to the baths, and which is inclined at an angle of 30° , half a foot of solid travertin is formed every year. A more compact rock is produced where the

*Section of travertin, San Vignone.*

water flows slowly, and the precipitation in winter, when there is least evaporation, is said to be more solid, but less in quantity by one fourth, than in summer. The rock is generally white; some parts of it are compact, and ring to the hammer; others are cellular, and with such cavities as are seen in the carious part of bone or the siliceous millstone of the Paris basin. A portion of it also below the village of San Vignone consists of incrustations of long vegetable tubes, and may be called tufa. Sometimes the travertin assumes precisely the botryoidal and mamillary forms, common to similar deposits in Auvergne, of a much older date; and, like them, it often scales off in thin, slightly undulating layers.

A large mass of travertin (*c*, Fig. 15.) descends the hill from the point where the spring issues, and reaches to the distance of about half a mile east of San Vignone. The beds take the slope of the hill at about an angle of 6° , and the planes of stratification are perfectly parallel. One stratum, composed of many layers, is of a compact nature, and fifteen feet thick: it serves as an excellent building stone, and a mass of

fifteen feet in length was, in 1828, cut out for the new bridge over the Orcia. Another branch of it (*a*, Fig. 15.) descends to the west, for 250 feet in length, of varying thickness, but sometimes 200 feet deep : it is then cut off by the small river Orcia, precisely as some glaciers in Switzerland descend into a valley till their progress is suddenly arrested by a transverse stream of water.

The abrupt termination of the mass of rock at the river, when its thickness is undiminished, clearly shows that it would proceed much farther if not arrested by the stream, over which it impends slightly. But it cannot encroach upon the channel of the Orcia, being constantly undermined, so that its solid fragments are seen strewed amongst the alluvial gravel. However enormous, therefore, the mass of solid rock may appear which has been given out by this single spring, we may feel assured that it is insignificant in volume when compared to that which has been carried to the sea since the time when it began to flow. What may have been the length of that period of time we have no data for conjecturing. In quarrying the travertin, Roman tiles have been sometimes found at the depth of five or six feet.

Baths of San Filippo.—On another hill, not many miles from that last mentioned, and also connected with Mount Amiata, the summit of which is about three miles distant, are the celebrated baths of San Filippo. The subjacent rocks consist of alternations of black slate, limestone, and serpentine, of highly inclined strata, belonging to the Apennine formation, and, as at San Vignone, near the boundary of a tertiary basin of marine origin, consisting chiefly of blue argillaceous marl. There are three warm springs here

containing carbonate and sulphate of lime, and sulphate of magnesia. The water which supplies the baths falls into a pond, where it has been known to deposit a solid mass *thirty feet thick*, in about *twenty years.** A manufactory of medallions in basso-relievo is carried on at these baths. The water is conducted by canals into several pits, in which it deposits travertin and crystals of sulphate of lime. After being thus freed from its grosser parts, it is conveyed by a tube to the summit of a small chamber, and made to fall through a space of ten or twelve feet. The current is broken in its descent by numerous crossed sticks, by which the spray is dispersed around upon certain moulds, which are rubbed lightly over with a solution of soap, and a deposition of solid matter like marble is the result, yielding a beautiful cast of the figures formed in the mould.† The geologist may derive from these experiments considerable light, in regard to the high slope of the strata at which some semi-crystalline precipitations can be formed; for some of the moulds are disposed almost perpendicularly, yet the deposition is nearly equal in all parts.

A hard stratum of stone, about a foot in thickness, is obtained from the waters of San Filippo in four months; and, as the springs are powerful, and almost uniform in the quantity given out, we are at no loss to comprehend the magnitude of the mass which descends the hill, which is a mile and a quarter in length and the third of a mile in breadth, in some places attaining a thickness of 250 feet at least. To what length it might have reached it is impossible to con-

* Dr. Grosse on the Baths of San Filippo. Ed. Phil. Journ. vol. ii. p. 292.

† Id. p. 297.

jecture, as it is cut off, like the travertin of San Vignone, by a small stream, where it terminates abruptly. The remainder of the matter held in solution is carried on probably to the sea.

Spheroidal structure in travertin.—But what renders this recent limestone of peculiar interest to the geologist, is the spheroidal form which it assumes, analogous to that of the cascade of Tivoli, afterwards to be described. The lamination of some of the concentric masses is so minute that sixty may be counted in the thickness of an inch, yet, notwithstanding these marks of gradual and successive deposition, sections are sometimes exhibited of what might seem to be perfect spheres. This tendency to a mammillary and globular structure arises from the facility with which the calcareous matter is precipitated in nearly equal quantities on all sides of any fragment of shell or wood, or any inequality of the surface over which the mineral water flows, the form of the nucleus being readily transmitted through any number of successive envelopes. But these masses can never be perfect spheres, although they often appear such when a transverse section is made in any line not in the direction of the point of attachment. There are, indeed, occasionally seen small oolitic and pisolithic grains, of which the form is globular; for the nucleus having been for a time in motion in the water, has received fresh accessions of matter on all sides.

In the same manner I have seen, on the vertical walls of large steam boilers, the heads of nails or rivets covered by a series of enveloping crusts of calcareous matter, usually sulphate of lime; so that a concretionary nodule is formed, preserving a nearly globular shape, when increased to a mass several

inches in diameter. In these, as in many travertins, there is often a combination of the concentric and radiated structure, and the last-mentioned character is one of those in which the English magnesian limestone agrees with the Italian travertins.

Another point of resemblance between these rocks, in other respects so dissimilar, is the interference of one sphere with another, and the occasional occurrence of cavities and vacuities, constituting what has been called a honeycombed structure, and also the frequent interposition of loose incoherent matter, between different solid spheroidal concretions. Yet, notwithstanding such points of analogy, Professor Sedgwick observes, that there are proofs of the concretionary arrangement in the magnesian limestone having taken place subsequently to original deposition, for in this case the spheroidal forms are often quite independent of the direction of the laminæ.*

Bulicami of Viterbo.—I must not attempt to describe all the places in Italy where the constant formation of limestone may be seen, as on the Silaro, near Pæstum, or on the Velino at Terni. But the hot springs in the vicinity of Viterbo, which I visited in 1828, deserve particular notice. Their petrifying powers were recorded by Dante, so long ago as the year 1300.

“ Quale del Bulicame esce'l ruscello.”

“ E'en as the rivulet from Bulicame,” &c.

Inj. xiv. 79.

About a mile and a half north of that town, in the midst of a sterile plain of volcanic sand and ashes, and near the hot baths called the Bulicami, a monticule is

* Geol. Trans. second series, vol. iii. p. 37.

seen, about 20 feet high and 500 yards in circumference, entirely composed of concretionary travertin. This rock has been largely quarried for lime, and much of it appears to have been removed. The laminæ are very thin, and their minute undulations so arranged, that the whole mass has at once a concentric and radiated structure. The beds dip at an angle of 40° or more from the centre of the monticule outwards. The whole mass has evidently been formed gradually, like the conical mounds of the geysers in Iceland, by a small jet or fountain of calcareous water, which overflowed from the summit of the monticule, but which is now dried up. A spring of hot water still issues (1828) in the neighbourhood, which is conveyed to an open tank used as a bath, the bottom and sides of which, as well as the open conduit which conveys the water, are encrusted with travertin.-

Campagna di Roma. — The country around Rome, like many parts of the Tuscan States already referred to, has been at some former period the site of numerous volcanic eruptions ; and the springs are still copiously impregnated with lime, carbonic acid, and sulphuretted hydrogen. A hot spring was discovered about 1827, near Civita Vecchia, by Signor Riccioli, which deposits alternate beds of a yellowish travertin, and a white granular rock, not distinguishable, in hand specimens, either in grain, colour, or composition, from statuary marble. There is a passage between this and ordinary travertin. The mass accumulated near the spring is in some places about six feet thick.

Lake of the Solfatara. — In the Campagna, between Rome and Tivoli, is the lake of the Solfatara, called also Lago di Zolfo (*lacus albula*), into which flows continually a stream of tepid water from a smaller lake,

situated a few yards above it. The water is a saturated solution of carbonic acid gas, which escapes from it in such quantities in some parts of its surface, that it has the appearance of being actually in ebullition. "I have found by experiment," says Sir Humphry Davy, "that the water taken from the most tranquil part of the lake, even after being agitated and exposed to the air, contained in solution more than its own volume of carbonic acid gas, with a very small quantity of sulphuretted hydrogen. Its high temperature, which is pretty constant at 80° of Fahr., and the quantity of carbonic acid that it contains, render it peculiarly fitted to afford nourishment to vegetable life. The banks of travertin are every where covered with reeds, lichen, confervæ, and various kinds of aquatic vegetables; and at the same time that the process of vegetable life is going on, the crystallizations of the calcareous matter, which is every where deposited, in consequence of the escape of carbonic acid, likewise proceed.—There is, I believe, no place in the world where there is a more striking example of the opposition or contrast of the laws of animate and inanimate nature, of the forces of inorganic chemical affinity, and those of the powers of life." *

The same observer informs us, that he fixed a stick in a mass of travertin covered by the water in the month of May, and in April following he had some difficulty in breaking, with a sharp pointed hammer, the mass which adhered to the stick, and which was several inches in thickness. The upper part was a mixture of light tufa and the leaves of confervæ: below this was a darker and more solid travertin, con-

* *Consolations in Travel*, pp. 123—125.

taining black and decomposed masses of conservæ; in the inferior part the travertin was more solid, and of a grey colour, but with cavities probably produced by the decomposition of vegetable matter.*

The stream which flows out of this lake fills a canal about nine feet broad and four deep, and is conspicuous in the landscape by a line of vapour which rises from it. It deposits calcareous tufa in this channel, and the Tiber probably receives from it, as well as from numerous other streams, much carbonate of lime in solution, which may contribute to the rapid growth of its delta. A large proportion of the most splendid edifices of ancient and modern Rome are built of travertin, derived from the quarries of Ponte Lucano, where there has evidently been a lake at a remote period, on the same plain as that already described. But the consideration of these would carry us beyond the times of history, and I shall conclude with one more example of the calcareous deposits of this neighbourhood,—those on the Anio.

Travertin of Tivoli. — The waters of the Anio incrust the reeds which grow on its banks, and the foam of the cataract of Tivoli forms beautiful pendant stalactites; but on the sides of the deep chasm into which the cascade throws itself, there is seen an extraordinary accumulation of horizontal beds of tufa and travertin, from four to five hundred feet in thickness. The section immediately under the temples of Vesta and the Sibyl, displays, in a precipice about four hundred feet high, some spheroids which are from *six to eight feet in diameter*, each concentric layer being about the eighth of an inch in thickness. The annexed

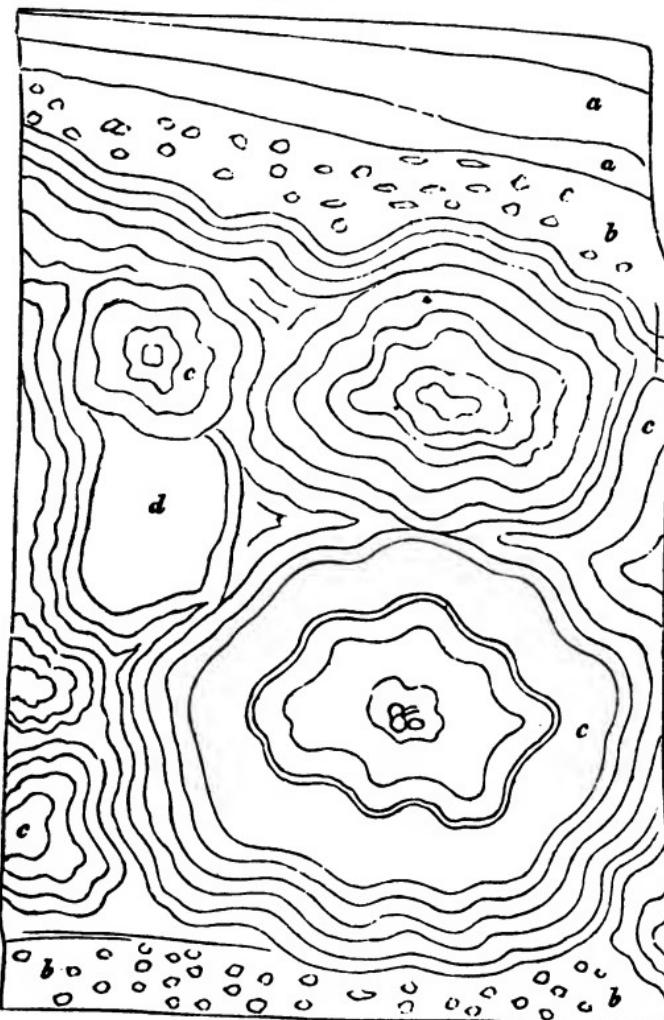
* *Consolations in Travel*, p. 127.

diagram exhibits about fourteen feet of this immense mass, as seen in the path cut out of the rock in descending from the temple of Vesta to the Grotto di Nettuno. I have not attempted to express in this drawing the innumerable thin layers of which these magnificent spheroids are composed, but the lines given mark some of the natural divisions into which they are separated by minute variations in the size or colour of the laminæ. The undulations also are much smaller, in proportion to the whole circumference, than in the drawing. The beds (*a a*) are of hard travertin and soft tufa; below them is a pisolite (*b*), the globules being of different sizes: underneath this appears a mass of concretionary travertin (*c c*), some of the spheroids being of the above-mentioned extraordinary size. In some places (as at *d*) there is a mass of amorphous limestone, or tufa, surrounded by concentric layers. At the bottom is another bed of pisolite (*b*), in which the small nodules are about the size and shape of beans, and some of them of filberts, intermixed with some smaller oolitic grains. In the tufaceous strata, wood is seen converted into a light tufa.

The following seems the most probable explanation of the origin of the rock in this singular position. The Anio flows through a deep irregular fissure or gorge in the Apennine limestone, which may have been caused by earthquakes. In this deep narrow channel there existed many small lakes, three of which have been destroyed, since the time of history, by the erosive action of the torrent, the last of them having remained down to the sixth century of our era.

We may suppose a similar lake of great depth to have existed at some remote period at Tivoli, and that, into this, the waters, charged with carbonate of

Fig. 16.



Section of spheroidal concretionary travertin under the Cascade of Tivoli.

lime, fell from a height inferior to that of the present cascade. Having, in their passage through the upper lakes, parted with their sand, pebbles, and coarse sediment, they only introduced into this lower pool drift-wood, leaves, and other buoyant substances. In seasons when the water was low, a deposit of ordinary

tufa, or of travertin, formed along the bottom ; but at other times, when the torrent was swollen, the pool must have been greatly agitated, and every small particle of carbonate of lime which was precipitated, must have been whirled round again and again in various eddies, until it acquired many concentric coats, so as to resemble oolitic grains. If the violence of the motion be sufficient to cause the globule to be suspended for a sufficient length of time, it would grow to the size of a pea, or much larger. Small fragments of vegetable stems being incrusted on the sides of the stream, and then washed in, would form the nucleus of oval globules, and others of irregular shapes would be produced by the resting of fragments for a time on the bottom of the basin, where, after acquiring an unequal thickness of travertin on one side, they would again be set in motion. Sometimes globules, projecting above the general level of a stratum, would attract, by chemical affinity, other matter in the act of precipitation, and thus growing on all sides, with the exception of the point of contact, might at length form spheroids nearly perfect and many feet in diameter. Masses might increase above and below, so that a vertical section might afterwards present the phenomenon so common at Tivoli, where the nucleus of some of the concentric circles has the appearance of having been suspended, without support, in the water, until it became a spheroidal mass of great dimensions.

It is probable that the date of the greater portion of this calcareous formation may be anterior to the era of history, for we know that there was a great cascade at Tivoli in very ancient times ; but, in the upper part of the travertin, is shown the hollow left by a wheel, in which the outer circle and the spokes

have been decomposed, and the spaces which they filled have been left void. It seems impossible to explain the position of this mould, without supposing that the wheel was imbedded before the lake was drained.

Calcareous springs in the Caucasus. — Pallas, in his journey along the Caucasus, a country now subject, from time to time, to be rent and fissured by violent earthquakes, enumerates a great many hot springs, which have deposited monticules of travertin precisely analogous in composition and structure to those of the baths of San Filippo and other localities in Italy. When speaking of the tophus-stone, as he terms these limestones, he often observes that it is *snow-white*, a description which is very applicable to the newer part of the deposit at San Filippo, where it has not become darkened by weathering. In many localities in the regions between the Caspian and Black Seas, where subterranean convulsions are frequent, travellers mention calc-sinter as an abundant product of hot springs. Near the shores of the Lake Urmia (or Maragha), for example, a marble which is much used in ornamental architecture, is rapidly deposited by a thermal spring.*

It is probable that some zoophytic and shelly limestones, which constitute coral reefs, may be supplied with carbonate of lime and other mineral ingredients from submarine springs, and that their heat, as well as their earthy and gaseous contents, may promote the development of corals, sponges, and testacea, just as vegetation is quickened by similar causes in the lake of the Solfatara before described. But of

* Von Hoff, *Geschichte, &c.* vol. ii. p. 114.

coral reefs and their probable origin I shall again have occasion to speak in the third book.

Sulphureous and gypseous springs.—The quantity of other mineral ingredients wherewith springs in general are impregnated, is insignificant in comparison to lime, and this earth is most frequently combined with carbonic acid. But, as sulphuric acid and sulphuretted hydrogen are very frequently supplied by springs, gypsum may, perhaps, be deposited largely in certain seas and lakes. The gypseous precipitates, however, hitherto known on the land, appear to be confined to a very few springs. Those at Baden, near Vienna, which feed the public bath, may be cited as examples. Some of these supply, singly, from 600 to 1000 cubic feet of water per hour, and deposit a fine powder, composed of a mixture of sulphate of lime with sulphur and muriate of lime.* In the Andes, at the Puenta del Inca, Lieutenant Brand found a thermal spring at the temperature of 91° F., containing a large proportion of gypsum with carbonate of lime and other ingredients.†

Siliceous springs. — Azores. — In order that water should hold a very large quantity of silica in solution, it seems necessary that it should be raised to a high temperature ‡; and as it may retain a greater heat under the pressure of the sea than in the atmosphere, submarine springs may, perhaps, be more charged with silex than any to which we have access. The hot springs of the Valle das Fenas, in the island of St. Michael, rising through volcanic rocks, precipitate

* C. Prevost, *Essai sur la Constitution Physique du Bassin de Vienne*, p. 10.

† Travels across the Andes, p. 240.

‡ Daubeny on Volcanos, p. 222.

vast quantities of siliceous sinter, as it is usually termed. Around the circular basin of the largest spring, which is between twenty and thirty feet in diameter, alternate layers are seen of a coarser variety of sinter mixed with clay, including grass, ferns, and reeds, in different states of petrifaction. Wherever the water has flowed sinter is found, rising in some places eight or ten inches above the ordinary level of the stream. The herbage and leaves, more or less incrusted with silex, are said to exhibit all the successive steps of petrifaction, from the soft state to a complete conversion into stone; but in some instances, alumina, which is likewise deposited from the hot waters, is the mineralizing material. Branches of the same ferns which now flourish in the island are found completely petrified, preserving the same appearance as when vegetating, except that they acquire an ash-grey colour. Fragments of wood, and one entire bed from three to five feet in depth, composed of reeds now common in the island, have become completely mineralized.

The most abundant variety of siliceous sinter occurs in layers from a quarter to half an inch in thickness, accumulated on each other often to the height of a foot and upwards, and constituting parallel, and for the most part horizontal, strata many yards in extent. This sinter has often a beautiful semi-opalescent lustre. One of the varieties differs from that of Iceland and Ischia in the larger proportion of water it contains, and in the absence of alumina and lime. A recent breccia is also in the act of forming, composed of obsidian, pumice, and scoriæ, cemented by siliceous sinter.*

* Dr. Webster on the Hot Springs of Furnas, Ed. Phil. Journ. vol. vi. p. 306.

Geysers of Iceland. — But the hot springs in various parts of Iceland, particularly the celebrated geysers, afford the most remarkable example of the deposition of silex.* The circular reservoirs into which the geysers fall, are lined in the interior with a variety of opal, and round the edges with sinter. The plants incrusted with the latter substance have much the same appearance as those incrusted with calcareous tufa in our own country. They consist of various grasses, the horse-tail (*Equisetum*), and leaves of the birch tree, which are the most common of all, though no trees of this species now exist in the surrounding country. The petrified stems also of the birch occur in a state much resembling agatized wood.†

By analysis of the water, Mr. Faraday has ascertained that the solution of the silex is promoted by the presence of the alkali, soda. He suggests that the deposition of silica in an insoluble state takes place partly because the water when cooled by exposure to the air is unable to retain as much silica as when it issues from the earth at a temperature of 180° or 190° Fahr.; and partly because the evaporation of the water decomposes the compound of silica and soda which previously existed. This last change is probably hastened by the carbonic acid of the atmosphere uniting with the soda. The alkali, when disunited from the silica, would readily be dissolved in and removed by running water.‡

Ischia. — It has been found, by analysis, that several of the thermal waters of Ischia are impregnated with

* See a cut of the Icelandic geyser, Book II. chap. xx.

† M. Robert, *Bulletin de la Soc. Géol. de France*, tom. vii. p. 11.

‡ Barrow's *Iceland*, p. 209.

a certain proportion of silica. Some of the hot vapours of that island are above the temperature of boiling water; and many fissures, near Monte Vico, through which the hot steam passes, are coated with a siliceous incrustation, first noticed by Dr. Thompson under the name of fiorite.

Ava, &c. — It has been often stated that the Danube has converted the external part of the piles of Trajan's bridge into silex; the Irawadi, in Ava, has been supposed, ever since the time of the Jesuit Padre Duchatz, to have the same petrifying power, as also Lough Neagh, in Ireland. Modern researches, however, in the Burman empire, have thrown doubt upon the lapidifying property of the Ava river*; there is certainly no foundation for the story in regard to Lough Neagh, and probably none in regard to the Danube.

Mineral waters, even when charged with a small proportion of silica, as those of Ischia, may supply certain species of corals, sponges, and infusoria, with matter for their siliceous secretions; but there is little doubt that rivers obtain silex in solution from another and far more general source, namely, the decomposition of felspar. When this mineral, which is so abundant an ingredient in the hypogene and trappean rocks, has disintegrated, it is found that the residue, called porcelain clay, contains a small proportion only of the silica which existed in the original felspar, the other part having been dissolved and removed by water.†

Ferruginous springs. — The waters of almost all springs contain some iron in solution; and it is a fact

* Dr. Buckland, Geol. Trans. second series, vol. ii. part iii, p. 384.

† See Elements of Geology; and Dr. Turner, Jam. Ed. New Phil. Journ. No. xxx. p. 246.

familiar to all, that many of them are so copiously impregnated with this metal, as to stain the rocks or herbage through which they pass, and to bind together sand and gravel into solid masses. We may naturally, then, conclude that this iron, which is constantly conveyed from the interior of the earth into lakes and seas, and which does not escape again from them into the atmosphere by evaporation, must act as a colouring and cementing principle in the subaqueous deposits now in progress. Geologists are aware that many ancient sandstones and conglomerates are bound together or coloured by iron.

Brine springs.—So great is the quantity of muriate of soda in some springs, that they yield one fourth of their weight in salt. They are rarely, however, so saturated, and generally contain, intermixed with salt, carbonate and sulphate of lime, magnesia, and other mineral ingredients. The brine springs of Cheshire are the richest in our country; those of Northwich being almost saturated. Those of Barton also, in Lancashire, and Droitwich in Worcestershire, are extremely rich.* They are known to have flowed for more than 1000 years, and the quantity of salt which they have carried into the Severn and Mersey must be enormous. These brine springs rise up through strata of sandstone and red marl, which contain large beds of rock salt. The origin of the brine, therefore, may be derived in this and many other instances from beds of fossil salt; but as muriate of soda is one of the products of volcanic emanations and of springs in volcanic regions, the original source of salt may be as deep seated as that of lava.

* L. Horner, Geol. Trans. vol. ii. p. 94.

The waters of the Dead Sea contain scarcely anything except muriatic salt, which lends countenance, observes Dr. Daubeny, to the volcanic origin of the surrounding country, these salts being frequent products of volcanic eruptions. Many springs in Sicily contain muriate of soda, and the "fiume salso," in particular, is impregnated with so large a quantity, that cattle refuse to drink of it.

A hot spring, rising through granite, at Saint Nectaire, in Auvergne, may be mentioned as one of many, containing a large proportion of muriate of soda, together with magnesia and other ingredients. *

Carbonated springs. — Auvergne. — Carbonic acid gas is very plentifully disengaged from springs in almost all countries, but particularly near active or extinct volcanos. This elastic fluid has the property of decomposing many of the hardest rocks with which it comes in contact, particularly that numerous class in whose composition felspar is an ingredient. It renders the oxide of iron soluble in water, and contributes, as was before stated, to the solution of calcareous matter. In volcanic districts these gaseous emanations are not confined to springs, but rise up in the state of pure gas from the soil in various places. The Grotto del Cane, near Naples, affords an example, and prodigious quantities are now annually disengaged from every part of the Limagne d'Auvergne, where it appears to have been developed in equal quantity from time immemorial. As the acid is invisible, it is not observed, except an excavation be made, wherein it immediately accumulates, so that it will extinguish a candle. There are some springs in this district, where the water is seen bubbling and boiling up with much

* *Annales de l'Auvergne*, tome i. p. 234.

noise, in consequence of the abundant disengagement of this gas. The whole vegetation is affected, and many trees, such as the walnut, flourish more luxuriantly than they would otherwise do in the same soil and climate — the leaves probably absorbing carbonic acid. This gas is found in springs rising through the granite near Clermont, as well as in the tertiary limestones of the Limagne.* In the environs of Pont-Gibaud, not far from Clermont, a rock belonging to the gneiss formation, in which lead-mines are worked, has been found to be quite saturated with carbonic acid gas, which is constantly disengaged. The carbonates of iron, lime, and manganese are so dissolved, that the rock is rendered soft, and the quartz alone remains unattacked. † Not far off is the small volcanic cone of Chaluzet, which once broke up through the gneiss, and sent forth a lava-stream.

Disintegrating effects of carbonic acid. — The disintegration of granite is a striking feature of large districts in Auvergne, especially in the neighbourhood of Clermont. This decay was called by Dolomieu, “la maladie du granite ;” and the rock may with propriety be said to have *the rot*, for it crumbles to pieces in the hand. The phenomenon may, without doubt, be ascribed to the continual disengagement of carbonic acid gas from numerous fissures.

In the plains of the Po, between Verona and Parma, especially at Villa Franca, south of Mantua, I observed great beds of alluvium, consisting chiefly of primary pebbles, percolated by spring water, charged with carbonate of lime and carbonic acid in great abundance. They are for the most part incrusted with calc-sinter :

* Le Coq, Annales de l'Auvergne, tome i. p. 217. May, 1828.

† Ann. Scient. de l'Auvergne, tome ii. June, 1829.

and the rounded blocks of gneiss, which have all the outward appearance of solidity, have been so disintegrated by the carbonic acid as readily to fall to pieces.

The subtraction of many of the elements of rocks by the solvent power of carbonic acid, ascending both in a gaseous state and mixed with spring-water in the crevices of rocks, must be one of the most powerful sources of those internal changes and re-arrangements of particles so often observed in strata of every age. The calcareous matter, for example, of shells, is often entirely removed and replaced by carbonate of iron, pyrites, silex, or some other ingredient, such as mineral waters usually contain in solution. It rarely happens, except in limestone rocks, that the carbonic acid can dissolve all the constituent parts of the mass; and for this reason, probably, calcareous rocks are almost the only ones in which great caverns and long winding passages are found.

Petroleum springs. — Springs impregnated with petroleum, and the various minerals allied to it, as bitumen, naphtha, asphaltum, and pitch, are very numerous, and are, in many cases, undoubtedly connected with subterranean fires, which raise or sublime the more subtle parts of the bituminous matters contained in rocks. Many springs in the territory of Modena and Parma, in Italy, produce petroleum in abundance; but the most powerful, perhaps, yet known, are those on the Irawadi, in the Burman empire. In one locality there are said to be 520 wells, which yield annually 400,000 hogsheads of petroleum.*

Fluid bitumen is seen to ooze from the bottom of

* Symes, Embassy to Ava, vol. ii. — Geol. Trans. second series, vol. ii. part iii. p. 388.

the sea, on both sides of the island of Trinidad, and to rise up to the surface of the water. Near Cape La Braye there is a vortex which, in stormy weather, according to Captain Mallet, gushes out, raising the water five or six feet, and covers the surface for a considerable space with petroleum, or tar; and the same author quotes Gumilla, as stating in his "Description of the Orinoco," that about seventy years ago, a spot of land on the western coast of Trinidad, near half way between the capital and an Indian village, sank suddenly, and was immediately replaced by a small lake of pitch, to the great terror of the inhabitants.*

Pitch lake of Trinidad. — It is probable that the great pitch lake of Trinidad owes its origin to a similar cause; and Dr. Nugent has justly remarked, that in that district all the circumstances are now combined from which deposits of pitch may have originated. The Orinoco has for ages been rolling down great quantities of woody and vegetable bodies into the surrounding sea, where, by the influence of currents and eddies, they may be arrested and accumulated in particular places. The frequent occurrence of earthquakes and other indications of volcanic action in those parts lend countenance to the opinion, that these vegetable substances may have undergone, by the agency of subterranean fire, those transformations and chemical changes which produce petroleum; and this may, by the same causes, be forced up to the surface, where, by exposure to the air, it becomes inspissated, and forms the different varieties of pure and earthy pitch, or asphaltum, so abundant in the island.†

* Dr. Nugent, Geol. Trans. vol. i. p. 69.

† Ibid. p. 67.

The bituminous shales, so common in geological formations of different ages, as also many stratified deposits of bitumen and pitch, seem clearly to attest that, at former periods, springs, in various parts of the world, were as commonly impregnated as now with bituminous matter, carried down, probably, by rivers into lakes and seas. It will, indeed, be easy to show that a large portion of the finer particles and the more crystalline substances, found in sedimentary rocks of different ages, are composed of the same elements as are now held in solution by springs, while the coarser materials bear an equally strong resemblance to the alluvial matter in the beds of existing torrents and rivers.

CHAPTER V.

REPRODUCTIVE EFFECTS OF RIVERS.

Division of deltas into lacustrine, mediterranean, and oceanic — Lake deltas — Growth of the delta of the Upper Rhone in the Lake of Geneva — Computation of the age of deltas — Recent deposits in Lake Superior — Deltas of inland seas — Rapid shallowing of the Baltic — Marine delta of the Rhone — Various proofs of its increase — Stony nature of its deposits — Delta of the Po, Adige, Isonzo, and other rivers entering the Adriatic — Rapid conversion of that gulf into land — Mineral characters of the new deposits — Delta of the Nile.

HAVING considered the destroying and transporting agency of running water, we have now to examine the reproductive effects of the same cause. To form a just conception of these effects will be more easy than to appreciate the excavating and removing force exerted by rivers and currents, for we shall now have the advantage of beholding in a palpable form the aggregate amount of matter which has accumulated at certain points in the lapse of ages. I shall therefore proceed to select some of the leading facts at present ascertained respecting the growth of deltas, and shall then offer some general observations on the quantity of sediment transported by rivers, and the manner of its distribution beneath the waters of lakes and seas.

Division of deltas into lacustrine, mediterranean, and oceanic. — Deltas may be divided into, first, those which are formed in lakes; secondly, those in inland

seas ; and, thirdly, those on the borders of the ocean. The most characteristic distinction between the lacustrine and marine deltas consists in the nature of the organic remains which become imbedded in their deposits ; for, in the case of a lake, it is obvious that these must consist exclusively of such genera of animals as inhabit the land or the waters of a river or lake ; whereas, in the other case, there will be an admixture, and most frequently a predominance of animals which inhabit salt water. In regard, however, to the distribution of inorganic matter, the deposits of lakes and inland seas are formed under very analogous circumstances, and may be distinguished from those on the shores of the great ocean, where the tides co-operating with currents give rise to another class of phenomena. In lakes and inland seas, even of the largest dimensions, the tides are almost insensible, but the currents, as will afterwards appear, sometimes run with considerable velocity.

DELTAS IN LAKES.

Lake of Geneva. — It is natural to begin our examination with an inquiry into the new deposits in lakes, as they exemplify the first reproductive operations in which rivers are engaged when they convey the detritus of rocks and the ingredients of mineral springs from mountainous regions. The accession of new land at the mouth of the Rhone, at the upper end of the Lake of Geneva, or the Leman Lake, presents us with an example of a considerable thickness of strata which have accumulated since the historical era. This sheet of water is about thirty-seven miles long, and its breadth is from two to eight miles. The shape of the bottom

is very irregular, the depth having been found by late measurements to vary from 20 to 160 fathoms.* The Rhone, where it enters at the upper end, is turbid and discoloured; but its waters, where it issues at the town of Geneva, are beautifully clear and transparent. An ancient town, called Port Vallais (*Portus Valesiae* of the Romans), once situated at the water's edge, at the upper end, is now more than a mile and a half inland — this intervening alluvial tract having been acquired in about eight centuries. The remainder of the delta consists of a flat alluvial plain, about five or six miles in length, composed of sand and mud, a little raised above the level of the river, and full of marshes.

Mr. De la Beche found, after numerous soundings in all parts of the lake, that there was a pretty uniform depth of from 120 to 160 fathoms throughout the central region, and, on approaching the delta, the shallowing of the bottom began to be very sensible at a distance of about a mile and three quarters from the mouth of the Rhone; for a line drawn from St. Gingoulph to Vevey, gives a mean depth of somewhat less than 600 feet, and from that part to the Rhone, the fluviatile mud is always found along the bottom.† We may state, therefore, that the new strata annually produced are thrown down upon a slope about two miles in length; so that, notwithstanding the great depth of the lake, the new deposits are not inclined at a high angle; the dip of the beds, indeed, is so slight, that they would be termed, in ordinary geological language, horizontal.

The strata probably consist of alternations of finer and coarser particles; for, during the hotter months

* De la Beche, Ed. Phil. Journ. vol. ii. p. 107. Jan. 1820.

† De la Beche, MS.

from April to August, when the snows melt, the volume and velocity of the river are greatest, and large quantities of sand, mud, vegetable matter, and drift-wood are introduced ; but, during the rest of the year, the influx is comparatively feeble, so much so, that the whole lake, according to Saussure, stands six feet lower. If, then, we could obtain a section of the accumulation formed in the last eight centuries, we should see a great series of strata, probably from 600 to 900 feet thick (the supposed original depth of the head of the lake), and nearly two miles in length, inclined at a very slight angle. In the mean time, a great number of smaller deltas are growing around the borders of the lake, at the mouths of rapid torrents, which pour in large masses of sand and pebbles. The body of water in these torrents is too small to enable them to spread out the transported matter over so extensive an area as the Rhone does. Thus, for example, there is a depth of eighty fathoms within half a mile of the shore, immediately opposite the great torrent which enters east of Ripaille, so that the dip of the strata in that minor delta must be about four times as great as those deposited by the main river at the upper extremity of the lake.*

Chronological computations of the age of deltas.—The capacity of this basin being now ascertained, it would be an interesting subject of inquiry, to determine in what number of years the Leman Lake will be converted into dry land. It would not be very difficult to obtain the elements for such a calculation, so as to approximate at least to the quantity of time required for the accomplishment of the result. The number of

* De la Beche, MS.

cubic feet of water annually discharged by the river into the lake being estimated, experiments might be made in the winter and summer months, to determine the proportion of matter held in suspension or in chemical solution by the Rhone. It would be also necessary to allow for the heavier matter drifted along at the bottom, which might be estimated on hydrostatical principles, when the average size of the gravel and the volume and velocity of the stream at different seasons were known. Supposing all these observations to have been made, it would be more easy to calculate the future than the former progress of the delta, because it would be a laborious task to ascertain, with any degree of precision, the original depth and extent of that part of the lake which is already filled up. Even if this information were actually obtained by borings, it would only enable us to approximate within a certain number of centuries to the time when the Rhone began to form its present delta; but this would not give us the date of the origin of the Leman Lake in its present form, because the river may have flowed into it for thousands of years, without importing any sediment whatever. Such would have been the case, if the waters had first passed through a chain of upper lakes; and that this was actually the fact, is indicated by the course of the Rhone between Martigny and the Lake of Geneva, and, still more decidedly, by the channels of many of its principal feeders.

If we ascend, for example, the valley through which the Dranse flows, we find that it consists of a succession of basins, one above the other, in each of which there is a wide expanse of flat alluvial lands, separated from the next basin by a rocky gorge, once evidently the barrier of a lake. The river has filled these lakes, one

after the other, and has partially cut through the barriers, which it is still gradually eroding to a greater depth. The examination of almost all valleys in mountainous districts affords similar proofs of the obliteration of a series of lakes, by the filling up of hollows and the cutting through of rocky barriers — a process by which running water ever labours to produce a more uniform declivity. Before, therefore, we can pretend even to hazard a conjecture as to the era at which any particular delta commenced, we must be thoroughly acquainted with the geographical features and geological history of the whole system of higher valleys which communicate with the main stream, and all the changes which they have undergone since the last series of convulsions which agitated and altered the face of the country.

Lake Superior. — Lake Superior is the largest body of fresh water in the world, being above 1700 geographical miles in circumference when we follow the sinuosities of its coasts; and its length, on a curved line drawn through its centre, being more than 400, and its extreme breadth above 150 geographical miles. Its surface is nearly as large as the whole of England. Its average depth varies from 80 to 150 fathoms; but, according to Captain Bayfield, there is reason to think that its greatest depth would not be overrated at 200 fathoms*, so that its bottom is, in some parts, nearly 600 feet below the level of the Atlantic, its surface about as much above it. There are appearances in different parts of this, as of the other Canadian lakes, leading us to infer that its waters formerly occupied a much higher level than they reach at present; for at a considerable distance from the present shores,

* Trans. of Lit. and Hist. Soc. of Quebec, vol. i. p. 5. 1829.

parallel lines of rolled stones and shells are seen rising one above the other, like the seats of an amphitheatre. These ancient lines of shingle are exactly similar to the present beaches in most bays, and they often attain an elevation of 40 or 50 feet above the present level.

As the heaviest gales of wind do not raise the waters more than three or four feet *, the elevated beaches must either be referred to the subsidence of the lake at former periods, in consequence of the wearing down of its barrier, or to the upraising of the shores by earthquakes, like those which have produced similar phenomena on the coast of Chili. The streams which discharge their waters into Lake Superior are several hundred in number, without reckoning those of smaller size; and the quantity of water supplied by them is many times greater than that discharged at the Falls of St Mary, the only outlet. The evaporation, therefore, is very great, and such as might be expected from so vast an extent of surface.

On the northern side, which is encircled by primary mountains, the rivers sweep in many large boulders with smaller gravel and sand, chiefly composed of granitic and trap rocks. There are also currents in the lake in various directions, caused by the continued prevalence of strong winds, and to their influence we may attribute the diffusion of finer mud far and wide over great areas; for, by numerous soundings made

* Captain Bayfield remarks, that Dr. Bigsby, to whom we are indebted for several communications respecting the geology of the Canadian lakes, was misinformed by the fur traders in regard to the extraordinary height (twenty or thirty feet) to which he asserts that the autumnal gales will raise the water of Lake Superior.—*Trans. of Lit. and Hist. Soc. of Quebec*, vol. i. p. 7. 1829.

during the late survey, it was ascertained that the bottom consists generally of a very adhesive clay, containing shells of the species at present existing in the lake. When exposed to the air, this clay immediately becomes indurated in so great a degree, as to require a smart blow to break it. It effervesces slightly with diluted nitric acid, and is of different colours in different parts of the lake; in one district blue, in another red, and in a third white, hardening into a substance resembling pipe-clay.* From these statements, the geologist will not fail to remark how closely these recent lacustrine formations in America resemble the tertiary argillaceous and calcareous marls of lacustrine origin in Central France. In both cases many of the genera of shells most abundant, as *Limnea* and *Planorbis*, are the same; and in regard to other classes of organic remains there must be the closest analogy, as I shall endeavour more fully to explain when speaking of the imbedding of plants and animals in recent deposits.

DELTAS OF INLAND SEAS.

Baltic.—Having thus briefly considered some of the lacustrine deltas now in progress, we may next turn our attention to those of inland seas.

The shallowing and conversion into land of many parts of the Baltic, especially the Gulfs of Bothnia and Finland, have been demonstrated by a series of accurate observations, for which we are in a great measure indebted to the animated controversy which has been kept up, since the middle of the last century, concerning the gradual lowering of the level of the Baltic. I shall revert to this subject when treating of the slow

* Trans. of Lit. and Hist. Soc. of Quebec, vol. i. p. 5. 1829.

and insensible upheaving of the land in certain parts of Sweden, a movement which produces an apparent fall in the level of the waters, both of the Baltic and the ocean.* It is only necessary to state in this place, that the rapid gain of low tracts of land near Torneo, Piteo, and Luleo, near the head of the Gulf of Bothnia, are due to the joint operation of two causes — the influx of sediment from numerous rivers, and a slow and general upward movement of the land itself, and bed of the sea, at the rate of several feet in a century.

Delta of the Rhone. — We may now turn our attention to some of the principal deltas of the Mediterranean, for no other inland sea affords so many examples of accessions of new land at the mouths of rivers within the records of authentic history. The lacustrine delta of the Rhone in Switzerland has already been considered, and its contemporaneous marine delta may now be described. Scarcely has the river passed out of the Lake of Geneva, before its pure waters are again filled with sand and sediment by the impetuous Arve, descending from the highest Alps, and bearing along in its current the granitic detritus annually brought down by the glaciers of Mont Blanc. The Rhone afterwards receives vast contributions of transported matter from the Alps of Dauphiny, and the primary and volcanic mountains of Central France; and when at length it enters the Mediterranean, it discolours the blue waters of that sea with a whitish sediment, for the distance of between six and seven miles,

* Since writing the third edition, I have visited Sweden, and removed the doubts which I before entertained and expressed respecting the alleged gradual elevation of the land in Scandinavia. — See Book II. chap. xviii.

throughout which space the current of fresh water is perceptible.

Proofs of its increase since historical periods.—Strabo's description of the delta is so inapplicable to its present configuration, as to attest a complete alteration in the physical features of the country since the Augustan age. It appears, however, that the head of the delta, or the point at which it begins to ramify, has remained unaltered since the time of Pliny, for he states that the Rhone divided itself at Arles into two arms. This is the case at present; one of the branches, the western, being now called Le Petit Rhône, which is again subdivided before entering the Mediterranean. The advance of the base of the delta, in the last eighteen centuries, is demonstrated by many curious antiquarian monuments. The most striking of these is the great and unnatural détour of the old Roman road from Ugernum to Beziers (*Bæterræ*) which went round by Nismes (*Nemausus*). It is clear that, when this was first constructed, it was impossible to pass in a direct line as now, across the delta, and that either the sea or marshes intervened in a tract now consisting of terra firma.* Astruc also remarks, that all the places on low lands, lying to the north of the old Roman road between Nismes and Beziers, have names of Celtic origin, evidently given to them by the first inhabitants of the country; whereas, the places lying south of that road, towards the sea, have names of Latin derivation, and were clearly founded after the Roman language had been introduced.

Another proof, also, of the great extent of land which has come into existence since the Romans con-

* Mém. d'Astruc, cited by Von Hoff, vol. i. p. 288.

quered and colonized Gaul, is derived from the fact, that the Roman writers never mention the thermal waters of Balaruc in the delta, although they were well acquainted with those of Aix, and others still more distant, and attached great importance to them, as they invariably did to all hot springs. The waters of Balaruc, therefore, must have formerly issued under the sea —a common phenomenon on the borders of the Mediterranean ; and on the advance of the delta they continued to flow out through the new deposits.

Among the more direct proofs of the increase of land, we find that Mese, described under the appellation of Mesua Collis by Pomponius Mela *, and stated by him to be nearly an island, is now far inland. Notre Dame des Ports, also, was a harbour in 898, but is now a league from the shore. Psalmodi was an island in 815, and is now two leagues from the sea. Several old lines of towers and sea-marks occur at different distances from the present coast, all indicating the successive retreat of the sea, for each line has in its turn become useless to mariners ; which may well be conceived, when we state that the tower of Tignaux, erected on the shore so late as the year 1737, is already a mile remote from it. †

By the confluence of the Rhone and the currents of the Mediterranean, driven by winds from the south, sand-bars are often formed across the mouths of the river : by these means considerable spaces become divided off from the sea, and subsequently from the river also, when it shifts its channels of efflux. As some of these lagoons are subject to the occasional

* Lib. ii. c. v.

† Bouche, Chorographie et Hist. de Provence, vol. i. p. 23., cited by Von Hoff, vol. i. p. 290.

ingress of the river when flooded, and of the sea during storms, they are alternately salt and fresh. Others, after being filled with salt water, are often lowered by evaporation till they become more salt than the sea; and it has happened, occasionally, that a considerable precipitate of muriate of soda has taken place in these natural salterns. During the latter part of Napoleon's career, when the excise laws were enforced with extreme rigour, the police was employed to prevent such salt from being used. The fluviatile and marine shells enclosed in these small lakes often live together in brackish water; but the uncongenial nature of the fluid usually produces a dwarfish size, and sometimes gives rise to strange varieties in form and colour.

Captain Smyth, in his survey of the coast of the Mediterranean, found the sea, opposite the mouth of the Rhone, to deepen gradually from four to forty fathoms, within a distance of six or seven miles, over which the discoloured fresh water extends; so that the inclination of the new deposits must be too slight to be appreciable in such an extent of section as a geologist usually obtains in examining ancient formations. When the wind blew from the south-west, the ships employed in the survey were obliged to quit their moorings; and when they returned, the new sand-banks in the delta were found covered over with a great abundance of marine shells. By this means, we learn how occasional beds of drifted marine shells may become interstratified with freshwater strata at a river's mouth.

Stony nature of its deposits. — That a great proportion, at least, of the new deposit in the delta of the Rhone consists of *rock*, and not of loose incoherent

matter, is perfectly ascertained. In the Museum at Montpellier is a cannon taken up from the sea near the mouth of the river, imbedded in a crystalline calcareous rock. Large masses, also, are continually taken up of an arenaceous rock, cemented by calcareous matter including multitudes of broken shells of recent species. The observations lately made on this subject corroborate the former statement of Marsilli, that the earthy deposits of the coast of Languedoc form a stony substance, for which reason he ascribes a certain bituminous, saline, and glutinous nature to the substances brought down with sand by the Rhone.* If the number of mineral springs charged with carbonate of lime which fall into the Rhone and its feeders in different parts of France be considered, we shall feel no surprise at the lapidification of the newly deposited sediment in this delta. It should be remembered, that the fresh water introduced by rivers being lighter than the water of the sea, floats over the latter, and remains upon the surface for a considerable distance. Consequently, it is exposed to as much evaporation as the waters of a lake; and the area over which the river-water is spread, at the junction of great rivers and the sea, may well be compared, in point of extent, to that of considerable lakes.

Now, it is well known, that so great is the quantity of water carried off by evaporation in some lakes, that it is nearly equal to the water flowing in; and in some inland seas, as the Caspian, it is quite equal. We may, therefore, well suppose, that, in cases where a strong current does not interfere, the greater portion not only of the matter held mechanically in suspension,

* Hist. Phys. de la Mer.

but of that also which is in chemical solution, may be precipitated at no great distance from the shore. When these finer ingredients are extremely small in quantity, they may only suffice to supply crustaceous animals, corals, and marine plants, with the earthy particles necessary for their secretions ; but whenever it is in excess (as generally happens if the basin of a river lie partly in a district of active or extinct volcanos), then will solid deposits be formed, and the shells will at once be included in a rocky mass.

Delta of the Po.—The Adriatic presents a great combination of circumstances favourable to the rapid formation of deltas — a gulf receding far into the land — a sea without tides or strong currents, and the influx of two great rivers, the Po and the Adige, besides numerous minor streams, draining on the one side a great crescent of the Alps, and on the other some of the loftiest ridges of the Apennines. From the northernmost point of the Gulf of Trieste, where the Isonzo enters, down to the south of Ravenna, there is an uninterrupted series of recent accessions of land, more than 100 miles in length, which within the last 2000 years have increased from *two to twenty miles in breadth*. The Isonzo, Tagliamento, Piave, Brenta, Adige, and Po, besides many other inferior rivers, contribute to the advance of the coastline, and to the shallowing of the gulf. The Po and the Adige may now be considered as entering by one common delta, for two branches of the Adige are connected with arms of the Po.

In consequence of the great concentration of the flooded waters of these streams since the system of embankment became general, the rate of encroachment of the new land upon the Adriatic, especially at

that point where the Po and Adige enter, is said to have been greatly accelerated. Adria was a seaport in the time of Augustus, and had, in ancient times, given its name to the gulf; it is now about twenty Italian miles inland. Ravenna was also a seaport, and is now about four miles from the main sea. Yet even before the practice of embankment was introduced, the alluvium of the Po advanced with rapidity on the Adriatic; for Spina, a very ancient city, originally built in the district of Ravenna, at the mouth of a great arm of the Po, was, so early as the commencement of our era, eleven miles distant from the sea.*

The greatest depth of the Adriatic, between Dalmatia and the mouths of the Po, is twenty-two fathoms; but a large part of the Gulf of Trieste and the Adriatic, opposite Venice, is less than twelve fathoms deep. Farther to the south, where it is less affected by the influx of great rivers, the gulf deepens considerably. Donati, after dredging the bottom, discovered the new deposits to consist partly of mud and partly of rock, the rock being formed of calcareous matter, incrusting shells. He also ascertained, that particular species of testacea were grouped together in certain places, and were becoming slowly incorporated with the mud, or calcareous precipitates.† Olivi, also, found some deposits of sand, and others of mud, extending half way across the gulf; and he states that their distribution along the bottom was evidently determined by the prevailing current.‡ It is probable, therefore, that the finer sediment of all the rivers at the head of the

* See Brocchi on the various writers on this subject. Conch. Foss. Subap. vol. i. p. 118.

† Ibid. vol. i. p. 39.

‡ Ibid. vol. ii. p. 94.

Adriatic may be intermingled by the influence of the current; and all the central parts of the gulf may be considered as slowly filling up with horizontal deposits, similar to those of the Subapennine hills, and containing many of the same species of shells. The Po merely introduces at present fine sand and mud; for it carries no pebbles farther than the spot where it joins the Trebia, west of Piacenza. Near the northern borders of the basin, the Isonzo, Tagliamento, and many other streams, are forming immense beds of sand and some conglomerate; for here some high mountains of Alpine limestone approach within a few miles of the sea.

In the time of the Romans, the hot-baths of Monfalcone were on one of several islands of Alpine limestone, between which and the mainland, on the north, was a channel of the sea, about a mile broad. This channel is now converted into a grassy plain, which surrounds the islands on all sides. Among the numerous changes on this coast, we find that the present channel of the Isonzo is several miles to the west of its ancient bed, in part of which, at Ronchi, the old Roman bridge which crossed the Via Appia was lately found buried in fluviatile silt.

Notwithstanding the present shallowness of the Adriatic, it is highly probable that its original depth was very great; for if all the low alluvial tracts were taken away from its borders and replaced by sea, the high land would terminate in that abrupt manner which generally indicates, in the Mediterranean, a great depth of water near the shore, except in those spots where sediment imported by rivers and currents has diminished the depth. Many parts of the Mediterranean are now ascertained to be above 2000

feet deep, close to the shore, as between Nice and Genoa; and even sometimes 6000 feet, as near Gibraltar. When, therefore, we find near Parma, and in other districts in the interior of the Italian peninsula, beds of horizontal tertiary marl attaining a thickness of about 2000 feet, or when we discover strata of inclined conglomerate, of the same age, near Nice, measuring above a thousand feet in thickness, and extending seven or eight miles in length, we behold nothing which the analogy of the deltas in the Adriatic might not lead us to anticipate.

Coast of Asia Minor.—Examples of the advance of the land upon the sea are afforded by the southern coast of Asia Minor. Captain Beaufort has pointed out in his Survey the great alterations effected since the time of Strabo, where havens are filled up, islands joined to the mainland, and where the whole continent has increased many miles in extent. Strabo himself, on comparing the outline of the coast in his time with its ancient state, was convinced, like our countryman, that it had gained very considerably upon the sea. The new-formed strata of Asia Minor consist of stone, not of loose, incoherent materials. Almost all the streamlets and rivers, like many of those in Tuscany and the south of Italy, hold abundance of carbonate of lime in solution, and precipitate travertin, or sometimes bind together the sand and gravel into solid sandstones and conglomerates: every delta and sand bar thus acquires solidity, which often prevents streams from forcing their way through them, so that their mouths are constantly changing their position.*

* Karamania, or a brief Description of the Coast of Asia Minor, &c. London, 1817.

Delta of the Nile. — That Egypt was “the gift of the Nile,” was the opinion of her priests before the time of Herodotus; and Rennell observes, that the “configuration and composition of the low lands leave no room for doubt that the sea once washed the base of the rocks on which the pyramids of Memphis stand, the *present* base of which is washed by the inundation of the Nile, at an elevation of 70 or 80 feet above the Mediterranean. But when we attempt to carry back our ideas to the remote period when the foundation of the delta was first laid, we are lost in the contemplation of so vast an interval of time.”* Herodotus observes, “that the country round Memphis seemed formerly to have been an arm of the sea gradually filled by the Nile, in the same manner as the Meander, Achelous, and other streams, had formed deltas. Egypt, therefore, he says, like the Red Sea, was once a long narrow bay, and both gulfs were separated by a small neck of land. If the Nile, he adds, should by any means have an issue into the Arabian Gulf, it might choke it up with earth in 20,000, or even, perhaps, in 10,000 years; and why may not the Nile have filled with mud a still greater gulf in the space of time which has passed before our age?”†

The bed of the river itself, says Sir J. G. Wilkinson, undergoes a gradual increase of elevation, varying in different places, and always lessening in proportion as the river approaches the sea. “This increase of elevation in perpendicular height is much smaller in Lower than in Upper Egypt; and in the delta it diminishes still more; so that, according to an approximate calculation, the land about Elephan-

* Geog. Syst. of Herod. vol. ii. p. 107.

† Euterpe, XI.

tine, or the first cataract, lat. $24^{\circ} 5'$, has been raised nine feet in 1700 years; at Thebes, lat. $25^{\circ} 43'$, about seven feet; and at Heliopolis and Cairo, lat. 30° , about five feet ten inches. At Rosetta and the mouths of the Nile, lat. $31^{\circ} 30'$, the diminution in the perpendicular thickness of the deposit is lessened in a much greater decreasing ratio than in the straitened valley of Central and Upper Egypt, owing to the great extent, east and west, over which the inundation spreads." *

For this reason the alluvial deposit does not cause the delta to protrude rapidly into the sea, although some ancient cities are now a mile or more inland, and the mouths of the Nile, mentioned by the earlier geographers, have been many of them silted up, and the outline of the coast entirely changed.

Homer has stated that "the distance from the Isle of Pharos to *Ægyptus* was as much as a vessel with a fair wind could perform in one day," whereas this island is now close to the shore, and united with it by an artificial dyke. Strabo and others explained this by supposing the progress of the delta since the days of Homer to have connected the island with the continent†; but Sir J. Wilkinson remarks that Homer has often used the word *Ægyptus* to signify the Nile; and he merely meant that Pharos was distant one day's sail from that river, or its principal mouth.

The bed of the Nile always keeps pace with the general elevation of the soil, and the banks of this river, like those of the Mississippi and its tributaries (see p. 353.), are much higher than the flat land at a distance, so that they are seldom covered during the highest inun-

* *Journ. of Roy. Geograph. Soc.* vol. ix. p. 432.

† *Lib. I.* part i. pp. 80. 98.

dations. In consequence of the gradual rise of the river's bed, the annual flood is constantly spreading over a wider area, and the alluvial soil encroaches on the desert, covering, to the depth of six or seven feet, the base of statues and temples which the waters never reached 3000 years ago. Although the sands of the Libyan deserts have in some places been drifted into the valley of the Nile, yet these aggressions, says Wilkinson, are far more than counterbalanced by the fertilizing effect of the water which now reaches farther inland towards the desert, so that the number of square miles of arable soil is greater at present than at any previous period.

Mud of the Nile. — The analysis of this mud gives nearly one half of argillaceous earth, and about one fourth of carbonate of lime, nearly one tenth of carbon, the remainder consisting of water, silex, oxide of iron, and carbonate of magnesia.*

In many places, as at Cairo, where artificial excavations have been made, or where the river has undermined its banks, the mud is seen to be thinly stratified, the upper part of each annual layer consisting of earth of a lighter colour than the lower, and the whole separating easily from the deposit of the succeeding year. These annual layers are variable in thickness; but, according to the calculations of Girard and Wilkinson, the mean annual thickness of a layer at Cairo cannot exceed that of a sheet of thin pasteboard, and a stratum of two or three feet must represent the accumulation of a thousand years.

The depth of the Mediterranean is about twelve fathoms at a small distance from the shore of the

* Girard, *Mém. sur l'Egypte*, tome i. pp. 348. 382.

delta ; it afterwards increases gradually to 50, and then suddenly descends to 380 fathoms, which is, perhaps, the original depth of the sea where it has not been rendered shallower by fluviatile matter. The progress of the delta in the last 2000 years affords, perhaps, no measure for estimating its rate of growth when it was an inland bay, and had not yet protruded itself beyond the coast-line of the Mediterranean. A powerful current now sweeps along the shores of Africa, from the Straits of Gibraltar to the prominent convexity of Egypt, the western side of which is continually the prey of the waves ; so that not only are fresh accessions of land checked, but ancient parts of the delta are carried away. By this cause Canopus and some other towns have been overwhelmed ; but to this subject I shall again refer when speaking of tides and currents.

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CHAPTER VI.

OCEANIC DELTAS.

Deltas of the Ganges and Burrampooter — Formation and destruction of islands — Abundance of crocodiles — Inundations — Delta of the Mississippi — Deposits of drift wood — Filling up of the Yellow Sea — Quantity of mud carried down by the Ganges — Formation of valleys illustrated by the growth of deltas — Grouping of new strata in general — Convergence of deltas — Conglomerates — Various causes of stratification — Direction of laminae — Remarks on the interchange of land and sea.

THE remaining class of deltas are those in which rivers, on entering the sea, are exposed to the influence of the tides. In this case it frequently happens that an estuary is produced, or negative delta, as Rennell termed it, where, instead of any encroachment of the land upon the sea, the ocean enters the river's mouth, and penetrates into the land beyond the general coast-line. Where this happens, the tides and currents are the predominating agents in the distribution of transported sediment. The phenomena, therefore, of such estuaries, will be treated of when the

movements of the ocean come under consideration. But whenever the volume of fresh water is so great as to counteract and almost neutralize the force of tides and currents, and in all cases where these agents have not sufficient power to remove to a distance the whole of the sediment periodically brought down by rivers, oceanic deltas are produced. Of these, I shall now select a few illustrative examples.

Delta of the Ganges. — The Ganges and the Burrampooter descend, from the highest mountains in the world, into a gulf which runs 225 miles into the continent. The Burrampooter is somewhat the larger river of the two; but it takes the name of the Megna, in lat. 24° N., when joined by a smaller stream so called, and afterwards loses this second name on its union with the principal arm of the Ganges, at the distance of about forty miles from the sea. The area of the delta of the Ganges (without including that of the Burrampooter, which has now become conterminous) is considerably more than double that of the Nile; and its head commences at a distance of 220 miles, in a direct line from the sea. Its base is two hundred miles in length, including the space occupied by the two great arms of the Ganges which bound it on either side. That part of the delta which borders on the sea is composed of a labyrinth of rivers and creeks, all filled with salt water, except those immediately communicating with the principal arm of the Ganges. This tract alone, known by the name of the Woods, or Sunderbunds, a wilderness infested by tigers and alligators, is, according to Rennell, equal in extent to the whole principality of Wales.*

* Account of the Ganges and Burrampooter Rivers, by Major Rennell, Phil. Trans. 1781.

On the sea-coast there are eight great openings, each of which has evidently, at some ancient period, served in its turn as the principal channel of discharge. Although the flux and reflux of the tide extend even to the head of the delta when the river is low ; yet, when it is periodically swollen by tropical rains, the velocity of the stream counteracts the tidal current, so that, except very near the sea, the ebb and flow become insensible. During the flood season, therefore, the Ganges almost assumes the character of a river entering a lake or inland sea ; the movements of the ocean being then subordinate to the force of the river, and only slightly disturbing its operations. The great gain of the delta in height and area takes place during the inundations ; and, during other seasons of the year, the ocean makes reprisals, scouring out the channels, and sometimes devouring rich alluvial plains.

So great is the quantity of mud and sand poured by the Ganges into the gulf in the flood season, that the sea only recovers its transparency at the distance of sixty miles from the coast. The general slope, therefore, of the new strata must be extremely gradual. By the charts recently published, it appears that there is a gradual deepening from four to about sixty fathoms, as we proceed from the base of the delta to the distance of about one hundred miles into the Bay of Bengal. At some few points seventy, or even one hundred, fathoms are obtained at that distance.

One remarkable exception, however, occurs to the regularity of the shape of the bottom ; for, opposite the middle of the delta, at the distance of thirty or forty miles from the coast, is a nearly circular space called the “swatch of no ground,” about fifteen miles in diameter, where soundings of 100, and even 130,

fathoms fail to reach the bottom. This phenomenon is the more extraordinary, since the depression occurs within five miles of the line of shoals ; and not only do the waters charged with Gangetic sediment pass over it continually ; but, during the monsoons, the sea, loaded with mud and sand, is beaten back in that direction towards the delta. As the mud is known to extend for eighty miles farther into the gulf, an enormous thickness of matter must have been deposited in "the swatch." We may conclude, therefore, either that the original depth of this part of the Bay of Bengal was excessive, or that subsidences have occurred in modern times. The latter conjecture is the less improbable, as the contiguous region of Chittagong has been convulsed in the historical era by earthquakes, and "the swatch" lies not far from that volcanic band which connects Sumatra and Barren island with Assam.*

Opposite the mouth of the Hoogly river, and immediately south of Sangor Island, four miles from the nearest land of the delta, a new islet was formed about twenty years ago, called Edmonstone Island, on the centre of which a beacon was erected as a landmark in 1817. In 1818 the island had become two miles long and half a mile broad, and was covered with vegetation and shrubs. Some houses were then built upon it, and in 1820 it was used as a pilot station. The severe gale of 1823 divided it into two parts, and so reduced its size as to leave the beacon standing out in the sea, where after remaining seven years it was washed away. The islet in 1836 had been converted by successive storms into a sand-bank, half a mile long, on which a sea-mark was placed.

* See M'Clelland's Report on Geol. of India, and map of Volcanic Bands, plate vi. Book ii. chap. 10.

Although there is evidence of gain at some points, the general progress of the coast is very slow ; for the tides, which rise from thirteen to sixteen feet, are actively employed in removing the alluvial matter, and diffusing it over a wide area. The new strata consist entirely of sand and fine mud ; such, at least, are the only materials which are exposed to view in regular beds on the banks of the numerous creeks. No substance so coarse as gravel occurs in any part of the delta, nor nearer the sea than 400 miles.

Islands formed and destroyed. — Major R. H. Colebrooke, in his account of the course of the Ganges, relates examples of the rapid filling up of some of its branches, and the excavation of new channels, where the number of square miles of soil removed in a short time (the column of earth being 114 feet high) was truly astonishing. Forty square miles, or 25,600 acres, are mentioned as having been carried away, in one place in the course of a few years.* The immense transportation of earthy matter by the Ganges and Megna is proved by the great magnitude of the islands formed in their channels during a period far short of that of a man's life. Some of these, many miles in extent, have originated in large sand-banks thrown up round the points at the angular turning of the river, and afterwards insulated by breaches of the stream. Others, formed in the main channel, are caused by some obstruction at the bottom. A large tree, or a sunken boat, is sometimes sufficient to check the current, and cause a deposit of sand, which accumulates till it usurps a considerable portion of the channel. The river then undermines its banks on each side, to supply the deficiency in its bed, and the island is after-

* Trans. of the Asiatic Society, vol. vii. p. 14.

wards raised by fresh deposits during every flood. In the great gulf below Luckipour, formed by the united waters of the Ganges and Megna, some of the islands, says Rennell, rival in size and fertility the Isle of Wight. While the river is forming new islands in one part, it is sweeping away old ones in others. Those newly formed are soon overrun with reeds, long grass, the *Tamarix Indica*, and other shrubs, forming impenetrable thickets, where tigers, buffaloes, deer, and other wild animals, take shelter. It is easy, therefore, to perceive, that both animal and vegetable remains must continually be precipitated into the flood, and sometimes become imbedded in the sediment which subsides in the delta.

Two species of crocodiles, of distinct genera, abound in the Ganges and its tributary and contiguous waters; and Mr. H. T. Colebrooke informs me, that he has seen both kinds in places far inland, many hundred miles from the sea. The Gangetic crocodile, or Gavial, (in correct orthography, Garial,) is confined to the fresh water, but the common crocodile frequents both fresh and salt; being much larger and fiercer in salt and brackish water. These animals swarm in the brackish water along the line of sand-banks where the advance of the delta is most rapid. Hundreds of them are seen together in the creeks of the delta, or basking in the sun on the shoals without. They will attack men and cattle, destroying the natives when bathing, and tame and wild animals which come to drink. "I have not unfrequently," says Mr. Colebrooke, "been witness to the horrid spectacle of a floating corpse seized by a crocodile with such avidity, that he half emerged above the water with his prey in his mouth." The geologist will not fail to observe how peculiarly the habits and distribution of these saurians

expose them to become imbedded in the horizontal strata of fine mud, which are annually deposited over many hundred square miles in the Bay of Bengal. The inhabitants of the land, which happen to be drowned or thrown into the water, are usually devoured by these voracious reptiles; but we may suppose the remains of the saurians themselves to be continually entombed in the new formations.

Inundations. — It sometimes happens, at the season when the periodical flood is at its height, that a strong gale of wind, conspiring with a high spring-tide, checks the descending current of the river, and gives rise to most destructive inundations. From this cause, in the year 1763, the waters at Luckipour rose six feet above their ordinary level, and the inhabitants of a considerable district, with their houses and cattle, were totally swept away.

The population of all oceanic deltas are particularly exposed to suffer by such catastrophes, recurring at considerable intervals of time; and we may safely assume that such tragical events have happened again and again since the Gangetic delta was inhabited by man. If human experience and forethought cannot always guard against these calamities, still less can the inferior animals avoid them; and the monuments of such disastrous inundations must be looked for in great abundance in strata of all ages, if the surface of our planet has always been governed by the same laws. When we reflect on the general order and tranquillity that reigns in the rich and populous delta of Bengal, notwithstanding the havoc occasionally committed by the depredations of the ocean, we perceive how unnecessary it is to attribute the imbedding of successive races of animals in older strata to extraordinary energy

in the causes of decay and reproduction in the infancy of our planet, or to those general catastrophes and sudden revolutions resorted to by some theorists.

Delta of the Mississippi. — As the delta of the Ganges may be considered a type of those formed on the borders of the ocean, it will be unnecessary to accumulate examples of others on a no less magnificent scale, as, for example, at the mouths of the Orinoco and Amazon. To these, however, I shall revert by and by, when treating of the agency of currents. The tides in the Mexican Gulf are so feeble that the delta of the Mississippi has somewhat of an intermediate character between an oceanic and mediterranean delta. A long narrow tongue of land is protruded, consisting simply of the banks of the river, wearing precisely the same appearance as in the inland plains during the periodical inundations, when nothing appears above water but the higher part of the sloping glacis before described.* This tongue of land has advanced many leagues since New Orleans was built. Great submarine deposits are also in progress, stretching far and wide over the bottom of the sea, which has become extremely shallow, not exceeding ten fathoms in depth. Opposite the mouth of the Mississippi large rafts of drift trees, brought down every spring, are matted together into a net-work, many yards in thickness, and stretching over hundreds of square leagues.† They afterwards become covered over with a fine mud, on which other layers of trees are deposited the year following, until numerous alternations of earthy and vegetable matter are accumulated.

* Chapter ii.

† Captain Hall's Travels in North America, vol. iii. p. 338.— See also above, chap. ii.

An observation of Darby, in regard to the strata composing part of this delta, deserves attention. In the steep banks of the Atchafalaya, an arm of the Mississippi before alluded to in our description of "the raft," the following section is observable at low water:—first, an upper stratum, consisting invariably of blueish clay, common to the banks of the Mississippi; below this a stratum of red ochreous earth, peculiar to Red River, under which the blue clay of the Mississippi again appears; and this arrangement is constant, proving, as that geographer remarks, that the waters of the Mississippi and the Red River occupied alternately, at some former periods, considerable tracts below their present point of union.* Such alternations are probably common in submarine spaces situated between two converging deltas; for, before the two rivers unite, there must almost always be a certain period when an intermediate tract will by turns be occupied and abandoned by the waters of each stream; since it can rarely happen that the season of highest flood will precisely correspond in each. In the case of the Red River and Mississippi, which carry off the waters from countries placed under widely distant latitudes, an exact coincidence in the time of greatest inundation is very improbable.

CONCLUDING REMARKS ON DELTAS.

Quantity of sediment in river water.—Very few satisfactory experiments have as yet been made, to enable us to determine, with any degree of accuracy, the mean quantity of earthly matter discharged annually

* Darby's Louisiana, p. 103.

into the sea by some one of the principal rivers of the earth. Hartsoeker computed the Rhine to contain in suspension, when most flooded, one part in a hundred of mud in volume * ; but it appears from two sets of experiments, recently made by Mr. Leonard Horner, at Bonn, that $\frac{1}{16000}$ th would have been a nearer approximation to the truth.† Mr. Barrow, in his journal, cited by Sir George Staunton, inferred from several observations, that the water of the Yellow River in China contained earthy matter in the proportion of one part to two hundred, and he calculated that it brought down in a single hour two million cubic feet of earth, or forty-eight million daily ; so that, if the Yellow Sea be taken to be 120 feet deep, it would require seventy days for the river to convert an English square mile into firm land, and 24,000 years to turn the whole sea into terra firma, assuming it to be 125,000 square miles in area.‡ Manfredi, the celebrated Italian hydrographer, conceived the average proportion of sediment in all the running water on the globe, which reached the sea, to be $\frac{1}{175}$, and he imagined that it would require a thousand years for the sediment carried down to raise the general level of the sea about one foot. Some writers, on the contrary, as De Maillet, have declared the most turbid waters to contain far less sediment. One of the most extraordinary statements is that of Major Rennell, in his excellent paper, before referred to, on the delta of the Ganges. “A glass of water,” he says, “taken out of this river when at its height, yields about one part in four of

* Comment. Bonon., vol. ii. part i. p. 297.

† Edin. New Phil. Journ., Jan. 1835.

‡ Staunton’s Embassy to China, Lond. 1797, 4to. vol. ii. p. 410.

mud. No wonder, then," he adds, " that the subsiding waters should quickly form a stratum of earth, or that the delta should encroach on the sea!" *

There must certainly be some mistake, perhaps a misprint, in the statement in the Phil. Trans.; and some have conjectured that the learned hydrographer meant one part in four hundred of mud. In the earlier editions of this work, I expressed my regret that so much inconsistency and contradiction should be found in the statements and speculations relative to this interesting subject; and I endeavoured to point out the high geological importance of reducing to arithmetical computation the aggregate amount of solid matter transported by certain large rivers to the sea. The deficiency of data has now been, in some degree, removed by the labours of the Rev. Mr. Everest, who has instituted a series of observations "On the earthy matter brought down by the Ganges" at Ghazipúr, in Bengal.†

The first step to be made in all such calculations is to ascertain the average volume of water passing annually down the channel of a river. This might easily be accomplished if the breadth, depth, and velocity of a stream were constant and uniform throughout the year; but as all these conditions are liable to vary according to the seasons, the problem becomes extremely complex. In the Ganges, as in other rivers in hot climates, there are periodical inundations, during which by far the greatest part of the annual discharge takes place; and the most important point, therefore,

* Phil. Trans. 1781.

† Journ. of Asiatic Soc., No. 6. p. 238. June, 1832. See also Mr. Prinsep, Gleanings in Science, vol. iii. p. 185.

to determine, is the mean breadth, depth, and velocity of the stream during this period.

Mr. Everest found that, in 1831, the number of cubic feet of water discharged by the Ganges per second was, during the

Rains, (4 months)	-	-	494,208
Winter, (5 months)	-	-	71,200
Hot weather, (3 months)	-	-	36,330

so that we may state in round numbers, that 500,000 cubic feet per second flow down during the four months of the flood season, from June to September, and less than 60,000 per second during the remaining eight months.

Having obtained the volume of water, we have next to inquire what is the proportion of solid matter contained in it; and for this purpose, a definite quantity, as, for example, a quart, is taken from the river on different days, sometimes from the middle of the current, and sometimes nearer the banks. This water is then evaporated, the solid residuum weighed, and the mean quantity of sediment thus ascertained, throughout the rainy season. The same observations must then be repeated for the other portions of the year.

In computing the quantity of water, Mr. Everest made no allowance for the decreased velocity of the stream near the bottom, presuming that it is compensated by the increased weight of matter held in suspension there. Probably the amount of sediment is by no means exaggerated by this circumstance; but rather under-rated, as the heavier grains of sand, which can never rise into the higher parts of the stream, are drifted along the bottom.

Now the average quantity of solid matter suspended in the water during the rains was, by weight $\frac{1}{28}$ th part; but, as the water is about one half the specific gravity of the dried mud, the solid matter discharged is $\frac{1}{56}$ th part in bulk, or 577 cubic feet per second. This gives a total of 6,082,041,600 cubic feet for the discharge in the 122 days of the rain. The proportion of sediment in the waters at other seasons was comparatively insignificant, the total amount during the five winter months being only 247,881,600 cubic feet, and during the three months of hot weather 38,154,240 cubic feet. The total annual discharge, then, would be 6,368,077,440 cubic feet.

In order to give some idea of the magnitude of this result, we will assume that the specific gravity of the dried mud is only one half that of granite (it would, however, be more): in that case, the earthy matter discharged in a year would equal 3,184,038,720 cubic feet of granite. Now about $12\frac{1}{2}$ cubic feet of granite weigh one ton; and it is computed that the great Pyramid of Egypt, if it were a solid mass of granite, would weigh about 6,000,000 tons. The mass of matter, therefore, carried down annually, would, according to this estimate, more than equal in weight and bulk forty-two of the great pyramids of Egypt, and that borne down in the four months of the rains would equal forty pyramids. But if, without any conjecture as to what may have been the specific gravity of the mud, we attend merely to the weight of solid matter actually proved by Mr. Everest to have been contained in the water, we find that the number of tons weight which passed down in the 122 days of the rainy season was 339,413,760, which would give the weight of fifty-six pyramids and a half; and in the

whole year 355,361,464 tons, or nearly the weight of sixty pyramids.

The base of the great Pyramid of Egypt covers eleven acres, and its perpendicular height is about five hundred feet. It is scarcely possible to present any picture to the mind which will convey an adequate conception of the mighty scale of this operation, so tranquilly and almost insensibly carried on by the Ganges, as it glides through its alluvial plain. It may, however, be stated, that if a fleet of more than eighty Indiamen, each freighted with about 1400 tons weight of mud, were to sail down the river every hour of every day and night for four months continuously, they would only transport from the higher country to the sea a mass of solid matter equal to that borne down by the Ganges in the four months of the flood season. Or the exertions of a fleet of about 2000 such ships going down daily with the same burden, and discharging it into the gulf, would be no more than equivalent to the operations of the great river. Yet, in addition to this, it is probable that the Burram-pooter conveys annually as much solid matter to the sea as the Ganges.

The most voluminous current of lava which has flowed from Etna within historical times was that of 1669. Ferrara, after correcting Borrelli's estimate, calculated the quantity of cubic yards of lava in this current at 140,000,000. Now, this would not equal in bulk one fifth of the sedimentary matter which is carried down in a single year by the Ganges, according to the estimate above explained; so that it would require five grand eruptions of Etna to transfer a mass of lava from the subterranean regions to the surface,

equal in volume to the mud carried down to the sea in one year by a single river in Bengal.

Grouping of Strata in Deltas.—The changes which have taken place in deltas, ever since the times of history, may suggest many important considerations in regard to the manner in which subaqueous sediment is distributed. Notwithstanding frequent exceptions, arising from the interference of a variety of causes, there are some general laws of arrangement which must evidently hold good in almost all the lakes and seas now filling up. If a lake, for example, be encircled on two sides by lofty mountains, receiving from them many rivers and torrents of different sizes, and if it be bounded on the other sides, where the surplus waters issue, by a comparatively low country, it is not difficult to define some of the leading geological features which must characterize the lacustrine formation, when this basin shall have been gradually converted into dry land by the influx of sediment. The strata would be divisible into two principal groups: the *older* comprising those deposits which originated on the side adjoining the mountains, where numerous deltas first began to form; and the *newer* group consisting of beds deposited in the more central parts of the basin, and towards the side farthest from the mountains. The following characters would form the principal marks of distinction between the strata in each series. The more ancient system would be composed, for the most part, of coarser materials, containing many beds of pebbles and sand, often of great thickness, and sometimes dipping at a considerable angle. These, with associated beds of finer ingredients, would, if traced round the borders of the basin, be seen to vary greatly in colour and mineral com-

position, and would also be very irregular in thickness. The beds, on the contrary, in the newer group, would consist of finer particles, and would be horizontal, or very slightly inclined. Their colour and mineral composition would be very homogeneous throughout large areas, and would differ from almost all the separate beds in the older series.

The following causes would produce the diversity here alluded to between the two great members of such lacustrine formations :— When the rivers and torrents first reach the edge of the lake, the detritus washed down by them from the adjoining heights sinks at once into deep water, all the heavier pebbles and sand subsiding near the shore. The finer mud is carried somewhat farther out, but not to the distance of many miles, for the greater part may be seen, as, for example, where the Rhone enters the Lake of Geneva, to fall down in clouds to the bottom not far from the river's mouth. Thus alluvial tracts are soon formed at the mouths of every torrent and river, and many of these in the course of ages become of considerable extent. Pebbles and sand are then transported farther from the mountains ; but in their passage they decrease in size by attrition, and are in part converted into mud and sand. At length some of the numerous deltas which are all directed towards a common centre approach near to each other—those of adjoining torrents become united, and each is merged, in its turn, in the delta of the largest river, which advances most rapidly into the lake, and renders all the minor streams, one after the other, its tributaries. The various mineral ingredients of all are thus blended together into one homogeneous mixture, and the sediment is poured out from a common channel into the lake.

As the average size of the transported particles decreases, while the force and volume of the main river augments, the newer deposits are diffused continually over a wider area, and are consequently more horizontal than the older. When at first there were many independent deltas near the borders of the basin, their separate deposits differed entirely from each other; one may have been charged, like the Arve where it joins the Rhone, with white sand, and sediment derived from granite — another may have been black, like many streams in the Tyrol, flowing from the waste of decomposing rocks of dark slate — a third may have been coloured by ochreous sediment, like the Red River in Louisiana — a fourth, like the Elsa in Tuscany, may have held much carbonate of lime in solution. At first they would each form distinct deposits of sand, gravel, limestone, marl, or other materials ; but after their junction new chemical combinations and a distinct colour would be the result, and the particles, having been conveyed ten, twenty, or a greater number of miles over alluvial plains, would become finer.

In deltas where the causes are more complicated, and where tides and currents partially interfere, the above description would only be applicable, with certain modifications ; but if a series of earthquakes accompany the growth of a delta, and change the levels of the land from time to time, as in the region where the Indus now enters the sea, and others hereafter to be mentioned, the phenomena will then depart still more widely from the ordinary type.

Convergence of Deltas. — If we possessed an accurate series of maps of the Adriatic for many thousand years, our retrospect would, without doubt, carry us

gradually back to the time when the number of rivers descending from the mountains into that gulf by independent deltas was far greater in number. The deltas of the Po and the Adige, for instance, would separate themselves within the *recent* era, as, in all probability, would those of the Isonzo and the Torre. If, on the other hand, we speculate on future changes, we may anticipate the period when the number of deltas will greatly diminish ; for the Po cannot continue to encroach at the rate of a mile in a hundred years, and other rivers to gain as much in six or seven centuries upon the shallow gulf, without new junctions occurring from time to time, so that Eridanus, "the king of rivers," will continually boast a greater number of tributaries. The Ganges and the Burrampooter have probably become confluent within the historical era ; and the date of the junction of the Red River and the Mississippi would, in all likelihood, have been known if America had not been so recently discovered. The union of the Tigris and the Euphrates must undoubtedly have been one of the modern geographical changes on our earth, and similar remarks might be extended to many other regions.

When the deltas of rivers, having many mouths, converge, a partial union at first takes place by the confluence of some one or more of their arms ; but it is not until the main trunks are connected above the head of the common delta, that a complete intermixture of their joint waters and sediment takes place. The union, therefore, of the Po and Adige, and of the Ganges and Burrampooter, is still incomplete. If we reflect on the geographical extent of surface drained by rivers such as now enter the Bay of Bengal, and then consider how complete the blending together of

the greater part of their transported matter has already become, and throughout how vast a delta it is spread by numerous arms, we no longer feel so much surprise at the area occupied by some ancient formations of homogeneous mineral composition. But our surprise will be still further lessened when we afterwards inquire into the action of tides and currents, in disseminating sediment.*

Formation of Conglomerates. — Along the base of the Maritime Alps, between Toulon and Genoa, the rivers, with few exceptions, are now forming strata of conglomerate and sand. Their channels are often several miles in breadth, some of them being dry, and the rest easily forded for nearly eight months in the year, whereas during the melting of the snow they are swollen, and a great transportation of mud and pebbles takes place. In order to keep open the main road from France to Italy, now carried along the sea-coast, it is necessary to remove annually great masses of shingle brought down during the flood-season. A portion of the pebbles are seen in some localities, as near Nice, to form beds of shingle along the shore, but the greater part are swept into a deep sea. The small progress made by the deltas of minor rivers on this coast need not surprise us, when we recollect that there is sometimes a depth of two thousand feet at a few hundred yards from the beach, as near Nice. Similar observations might be made respecting a large proportion of the rivers in Sicily, and, among others, respecting that which, immediately north of the port of Messina, hurries annually vast masses of granitic pebbles into the sea.

* See Chap. ix.

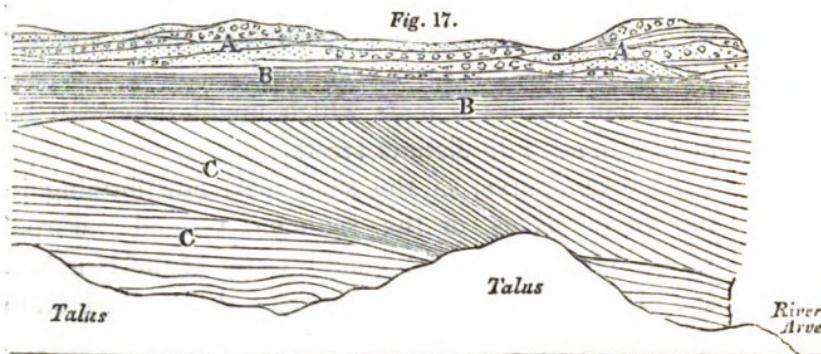
Causes of Stratification in Deltas.—The stratified arrangement which is observed to prevail so generally in aqueous deposits is most frequently due to variations in the velocity of running water, which cannot sweep along particles of more than a certain size and weight when moving at a given rate. Hence, as the force of the stream augments or decreases, the materials thrown down in successive layers at particular places are rudely sorted, according to their dimensions, forms, and specific gravity. Where this cause has not operated, as where sand, mud, and fragments of rock are conveyed by a glacier, a confused heap of rubbish devoid of all stratification is produced.

Natural divisions are also occasioned in deltas by the interval of time which separates annually the deposition of matter during the periodical rains, or melting of the snow upon the mountains. The deposit of each year may acquire some degree of consistency before that of the succeeding year is superimposed. A variety of circumstances also give rise annually, or sometimes from day to day, to slight variations in colour, fineness of the particles, and other characters, by which alternations of strata distinct in texture, and mineral ingredients, must be produced. Thus, for example, at one period of the year, drift wood may be carried down, and at another mud, as was before stated to be the case in the delta of the Mississippi; or at one time, when the volume and velocity of the stream are greatest, pebbles and sand may be spread over a certain area, over which, when the waters are low, fine matter or chemical precipitates are formed. During inundations, the turbid current of fresh water often repels the sea for many miles; but when the river is low, salt water again occupies the same space. When two

deltas are converging, the intermediate space is often, for reasons before explained, alternately the receptacle of different sediments derived from the converging streams. (See p. 9.) The one is, perhaps, charged with calcareous, the other with argillaceous matter; or one sweeps down sand and pebbles, the other impalpable mud. These differences may be repeated, with considerable regularity, until a thickness of hundreds of feet of alternating beds is accumulated. The multiplication, also, of shells and corals in particular spots, and for limited periods, gives rise occasionally to lines of separation, and divides a mass which might otherwise be homogeneous into distinct strata.

An examination of the shell marl now forming in the Scotch lakes, or the sediment termed "warp," which subsides from the muddy water of the Humber, and other rivers, shews that recent deposits are often composed of a great number of extremely thin layers, either even or slightly undulating, and preserving a general parallelism to the planes of stratification. Sometimes, however, the laminæ in modern strata are disposed diagonally at a considerable angle, which appears to take place where there are conflicting movements in the waters. In January, 1829, I visited, in company with Professor L. A. Necker, of Geneva, the confluence of the Rhone and Arve, when those rivers were very low, and were cutting channels through the vast heaps of débris thrown down from the waters of the Arve, in the preceding spring. One of the sand-banks which had formed, in the spring of 1828, where the opposing currents of the two rivers neutralized each other, and caused a retardation in the motion, had been undermined; and the following is an exact representation of the arrangement of laminæ exposed

in a vertical section. The length of the portion here seen is about twelve feet, and the height five. The strata A A consist of irregular alternations of pebbles and sand in undulating beds: below these are seams of very fine sand B B, some as thin as paper, others about a quarter of an inch thick. The strata c c are composed of layers of fine greenish-grey sand, as thin as paper. Some of the inclined beds will be seen to



Section of a sand bank in the bed of the Arve at its confluence with the Rhone, showing the stratification of deposits where currents meet.

be thicker at their upper, others at their lower extremity, the inclination of some being very considerable. These layers must have accumulated one on the other by lateral apposition, probably when one of the rivers was very gradually increasing or diminishing in velocity, so that the point of greatest retardation caused by their conflicting currents shifted slowly, allowing the sediment to be thrown down in successive layers on a sloping bank. The same phenomenon is exhibited in older strata of all ages.*

Constant interchange of land and sea. — I may here conclude my remarks on deltas, observing that, im-

* See Elements of Geology by the Author.

perfect as is our information of the changes which they have undergone within the last three thousand years, they are sufficient to show how constant an interchange of sea and land is taking place on the face of our globe. In the Mediterranean alone, many flourishing inland towns, and a still greater number of ports, now stand where the sea rolled its waves since the era of the early civilization of Europe. If we could compare with equal accuracy the ancient and actual state of all the islands and continents, we should probably discover that millions of our race are now supported by lands situated where deep seas prevailed in earlier ages. In many districts not yet occupied by man, land animals and forests now abound where ships once sailed, and on the other hand, we shall find, on inquiry, that inroads of the ocean have been no less considerable. When to these revolutions, produced by aqueous causes, we add analogous changes wrought by igneous agency, we shall, perhaps, acknowledge the justice of the conclusion of Aristotle, who declared that the whole land and sea on our globe periodically changed places.*

* See Vol. i. p. 22.

CHAPTER VII.

DESTROYING AND TRANSPORTING EFFECTS OF TIDES AND CURRENTS.

Differences in the rise of the tides — Rennell's Account of the Lagullas and Gulf currents — Velocity of currents — Causes of currents — Action of the sea on the British coast — Shetland Islands — Large blocks removed — Effects of lightning — Isles reduced to clusters of rocks — Orkney Isles — Waste of East coast of Scotland — and East coast of England — Waste of the cliffs of Holderness, Norfolk, and Suffolk — Silting up of estuaries — Origin of submarine forests — Yarmouth estuary — Suffolk coast — Dunwich — Essex coast — Estuary of the Thames — Goodwin Sands — Coast of Kent — Formation of Straits of Dover — South coast of England — Sussex — Hants — Dorset — Portland — Origin of the Chesil Bank — Cornwall — Coast of Brittany.

ALTHOUGH the movements of great bodies of water, termed tides and currents, are in general due to very distinct causes, their effects cannot be studied separately; for they produce, by their joint action, those changes which are objects of geological interest. These forces may be viewed in the same manner as we before considered rivers, first, as employed in destroying portions of the solid crust of the earth, and removing them to other places; secondly, as reproductive of new strata.

Tides. — It would be superfluous at the present day to offer any remarks on the cause of the tides. They are not perceptible in lakes, or in most inland seas;

in the Mediterranean even, deep and extensive as is that sea, they are scarcely sensible to ordinary observation, their effects being quite subordinate to those of the winds and currents. In some places, however, as in the Straits of Messina, there is an ebb and flow to the amount of two feet and upwards; at Naples and at the Euripus, of twelve or thirteen inches; and at Venice, according to Rennell, of five feet.* In the Syrtes, also, of the ancients, two wide shallow gulfs, which penetrate very far within the northern coast of Africa, between Carthage and Cyrene, the rise is said to exceed five feet.†

In islands remote from any continent, the ebb and flow of the ocean is very slight, as at St. Helena, for example, where it is rarely above three feet.‡ In any given line of coast, the tides are greatest in narrow channels, bays, and estuaries, and least in the intervening tracts where the land is prominent. Thus, at the entrance of the estuary of the Thames and Medway, the rise of the spring tides is eighteen feet; but when we follow our eastern coast from thence northward, towards Lowestoff and Yarmouth, we find a gradual diminution, until, at the places last mentioned, the highest rise is only seven or eight feet. From this point there begins again to be an increase, so that at Cromer, where the coast again retires towards the west, the rise is sixteen feet; and towards the extremity of the gulf called "the Wash," as at Lynn and in Boston deeps, it is from twenty-two to twenty-four feet, and in some extraordinary cases twenty-six feet. From

* Geog. of Herod. vol. ii. p. 331.

† Ibid. p. 328.

‡ Romme, Vents et Courans, vol. ii. p. 2. Rev. F. Fallows, Quart. Journ. of Science, March, 1829.

thence again there is a decrease towards the north, the elevation at the Spurn Point being from nineteen to twenty feet, and at Flamborough Head and the Yorkshire coast from fourteen to sixteen feet.*

At Milford Haven in Pembrokeshire, at the mouth of the Bristol Channel, the tides rise thirty-six feet; and at King-Road near Bristol, forty-two feet. At Chepstow on the Wye, a small river which opens into the estuary of the Severn, they reach fifty feet, and sometimes sixty-nine, and even seventy-two feet.† A current which sets in on the French coast, to the west of Cape La Hague, becomes pent up by Guernsey, Jersey, and other islands, till the rise of the tide is from twenty to forty-five feet, which last height it attains at Jersey, and at St. Malo, a seaport of Brittany.

There are, however, some coasts where the tides seem to offer an exception to the rule above mentioned; for while there is scarcely any rise in the estuary of the Plata in S. America, there is an extremely high tide on the open coast of Patagonia, farther to the south. Yet even in this region the tides reach their greatest elevation (about fifty feet) in the Straits of Magellan, and so far at least they conform to the general rule.

Currents.—The most extensive and best determined system of currents, is that which has its source in the Indian Ocean under the influence of the trade winds; and which, after doubling the Cape of Good Hope, inclines to the northward, along the western coast of Africa, then crosses the Atlantic, near the equator, and is lost in the Caribbean Sea, yet seems to be again

* The heights of these tides are given on the authority of Captain Hewett, R. N.

† On the authority of Captain Beaufort, R. N.

revived in the current which issues from the gulf of Mexico, by the Straits of Bahama, and flows rapidly in a north-easterly direction by the bank of Newfoundland, towards the Azores.

We learn from the posthumous work of Rennell on this subject, that the Lagullas current, so called from the cape and bank of that name, is formed by the junction of two streams, flowing from the Indian Ocean; the one from the channel of Mozambique, down the south-east coast of Africa; the other, from the ocean at large. The collective stream is from ninety to one hundred miles in breadth, and runs at the rate of from two and a half to more than four miles per hour. It is at length turned westward by the Lagullas bank, which rises from a sea of great depth to within one hundred fathoms of the surface. It must, therefore be inferred, says Rennell, that the current here is more than one hundred fathoms deep, otherwise the main body of it would pass across the bank, instead of being deflected eastward, so as to flow round the Cape of Good Hope. From this cape it flows northward, along the western coast of Africa, taking the name of the South Atlantic current. It then enters the Bight, or Bay of Benin, and is turned westward, partly by the form of the coast there, and partly, perhaps, by the Guinea current, which runs from the north into the same great bay. From the centre of this bay proceeds the Equatorial current, holding a westerly direction across the Atlantic, which it traverses, from the coast of Guinea to that of Brazil, flowing afterwards by the shores of Guiana to the West Indies. The breadth of this current varies from 160 to 450 geographical miles, and its velocity is from twenty-five to seventy-nine

miles per day, the mean rate being about thirty miles. The length of its whole course is about 4000 miles. As it skirts the coast of Guiana, it is increased by the influx of the waters of the Amazon and Orinoco, and by their junction acquires accelerated velocity. After passing the island of Trinidad, it expands, and is almost lost in the Caribbean Sea; but there appears to be a general movement of that sea towards the Mexican gulf, which discharges the most powerful of all currents through the Straits of Florida, where the waters run in the northern part with a velocity of five miles an hour, having a breadth of from thirty-five to fifty miles.

The temperature of the gulf of Mexico is 86° , in summer, or 6° higher than that of the ocean, in the same parallel (25° N. lat.), and a large proportion of this warmth is retained, even where the stream reaches the 43° N. lat. After issuing from the Straits of Florida, the current runs in a northerly direction to Cape Hatteras, in North Carolina, about 35° N. lat., where it is more than seventy miles broad, and still moves at the rate of seventy-five miles per day. In about the 40° N. lat., it is turned more towards the Atlantic by the extensive banks of Nantucket, and St. George, which are from 200 to 300 feet beneath the surface of the sea; a clear proof that the current exceeds that depth. On arriving near the Azores, the stream widens, and overflows, as it were, forming a large expanse of warm water in the centre of the North Atlantic, over a space of 200 or 300 miles from north to south, and having a temperature of from 8° to 10° Fahr. above the surrounding ocean. The whole area, covered by the gulf water, is estimated by Rennell at 2000 miles in length, and, at a mean, 350 miles in breadth;

an area more extensive than that of the Mediterranean. The warm water has been sometimes known to reach the Bay of Biscay, still retaining five degrees of temperature above that of the adjoining ocean, and a branch of the gulf current occasionally drifts fruits, plants, and wood, the produce of America, and the West Indies, to the shores of Ireland, and the Hebrides.

From the above statements we may understand why Rennell has characterized some of the principal currents as oceanic rivers, which he describes as being from 50 to 250 miles in breadth, and having a rapidity exceeding that of the largest navigable rivers of the continents, and so deep as to be sometimes obstructed, and occasionally turned aside, by banks, the tops of which do not rise within forty, fifty, or even one hundred fathoms of the surface of the sea.*

Greatest Velocity of Currents. — The ordinary velocity of the principal currents of the ocean is from one to three miles per hour; but when the boundary lands converge, large bodies of water are driven gradually into a narrow space, and then wanting lateral room are compelled to raise their level. Whenever this occurs, their velocity is much increased. The current which runs through the Race of Alderney, between the island of that name and the main land, has a velocity of above eight English miles an hour. Captain Hewett found that in the Pentland Firth the stream, in ordinary spring tides, runs ten miles and a half an hour, and about thirteen miles during violent storms. The greatest velocity of the tidal current through the " Shoots," or New Passage, in the Bristol Channel, is

* Rennell on Currents, p. 58.

fourteen English miles an hour ; and Captain King observed, in his recent survey of the Straits of Magellan, that the tide ran at the same rate through the “ First Narrows,” and about eight geographical miles an hour in other parts of those straits.

Causes of Currents.—That movements of no inconsiderable magnitude should be impressed on an expansive ocean, by winds blowing for many months in one direction, may easily be conceived, when we observe the effects produced in our own seas by the temporary action of the same cause. It is well known that a strong south-west or north-west wind invariably raises the tides to an unusual height along the east coast of England and in the Channel ; and that a north-west wind of any continuance causes the Baltic to rise two feet and upwards above its ordinary level. Smeaton ascertained by experiment that, in a canal four miles in length, the water was kept up four inches higher at one end than at the other, merely by the action of the wind along the canal ; and Rennell informs us that a large piece of water, ten miles broad, and generally only three feet deep, has, by a strong wind, had its waters driven to one side, and sustained so as to become six feet deep, while the windward side was laid dry.*

As water, therefore, he observes, when pent up so that it cannot escape, acquires a higher level, so, in a place where it can escape, the same operation produces a current ; and this current will extend to a greater or less distance, according to the force by which it is produced.

Currents flowing alternately in opposite directions

* Rennell on the Channel-current.

are also occasioned by the rise and fall of the tides. The effect of this cause is, as before observed, most striking in estuaries and channels between islands.

A third cause of oceanic currents is evaporation by solar heat, of which the great current setting through the Straits of Gibraltar into the Mediterranean is a remarkable example, and will be fully considered in the next chapter. A stream of colder water also flows from the Black Sea into the Mediterranean. It must happen in many other parts of the world that large quantities of water raised from one tract of the ocean by solar heat, are carried to some other where the vapour is condensed and falls in the shape of rain, and this in flowing back again to restore equilibrium, will cause sensible currents.

These considerations naturally lead to the inquiry whether the level of those seas out of which currents flow is higher than that of seas into which they flow. Arago is of opinion that, so far as observations have gone, there are no exact proofs of any such difference of level. At the same time he admits the important and remarkable fact that the level of the Mediterranean near Alexandria is lower by 26 feet 6 inches than the Red Sea near Suez at low water, and about 30 feet lower than the Red Sea at the same place at high water. This result was obtained during the French expedition to Egypt, from the measurements of M. Lepère.*

It was formerly imagined that there was an equal, if not greater diversity, in the relative levels of the Atlantic and Pacific, on the opposite sides of the isthmus of Panama. But the levellings carried across

* An. du Bureau des Long. pour l'an 1836.

that isthmus by Mr. Lloyd, in 1828, to ascertain the relative height of the Pacific Ocean at Panama, and of the Atlantic at the mouth of the river Chagres, have shown, that the difference of mean level between those oceans is not considerable, and contrary to expectation the difference which does exist is in favour of the greater height of the Pacific. According to the result of this survey, on which great dependence may be placed, the mean height of the Pacific is three feet and a half, or 3.52 above the Atlantic, if we assume the mean level of a sea to coincide with the mean between the extremes of the elevation and depression of the tides; for between the extreme levels of the greatest tides in the Pacific, at Panama, there is a difference of 27.44 feet; and at the usual spring tides 21.22 feet: whereas at Chagres this difference is only 1.16 feet, and is the same at all seasons of the year.

The tides, in short, in the Caribbean Sea are scarcely perceptible, not equalling those in some parts of the Mediterranean, whereas the rise is very high in the Bay of Panama; so that the Pacific is at high tide lifted up several feet above the surface of the Gulf of Mexico, and then at low water let down as far below it.* But astronomers are agreed that, on mathematical principles, the rise of the tidal wave above the mean level of a particular sea must be greater than the fall below it; and although the difference has been hitherto supposed insufficient to cause an appreciable error, it is, nevertheless, worthy of observation, that the error, such as it may be, would tend to reduce the small difference, now inferred, from the observations of Mr. Lloyd, to exist between the levels of the two oceans.

* Phil. Trans., 1830, p. 59.

There is still another way in which heat and cold must occasion great movements in the ocean, a cause to which, perhaps, currents are principally due. It is now ascertained that there is in sea water no point as in fresh water, at which an increase of cold causes the fluid to begin again to expand. In the ocean, therefore, whenever the temperature of the surface is lowered, condensation takes place, and the superficial water, having its specific gravity increased, falls to the bottom, upon which lighter water rises immediately and occupies its place. When this circulation of ascending and descending currents has gone on for a certain time in high latitudes, the inferior parts of the sea are made to consist of colder or heavier fluid than the corresponding depths of the ocean between the tropics. If there be a free communication, if no chain of submarine mountains divide the polar from the equatorial basins, a horizontal movement will arise by the flowing of colder water from the poles to the equator, and there will then be a reflux of warmer superficial water from the equator to the poles. A well-known experiment has been adduced to elucidate this mode of action in explanation of the "trade winds."* If a long trough, divided in the middle by a sluice or partition, have one end filled with water and the other with quicksilver, both fluids will remain quiet so long as they are divided; but when the sluice is drawn up, the heavier fluid will rush along the bottom of the trough, while the lighter, being displaced, will rise, and, flowing in an opposite direction, spread itself at

* See Capt. B. Hall's clear Explanation of the Theory of the Trade Winds, *Fragments of Voyages*, second series, vol. i., and his letter in the Appendix to Daniell's Meteorology.

the top. In like manner the expansion and contraction of sea-water by heat and cold have a tendency to set under-currents in motion from the poles to the equator, and to cause counter-currents at the surface which are impelled in a direction contrary to that of the prevailing trade winds. The geographical and other circumstances being very complicated, we cannot expect to trace separately the movements due to each cause, but must be prepared for many anomalies, especially as the configuration of the bed of the ocean must often modify and interfere with the course of the inferior currents, as much as the position and form of continents and islands alter the direction of those on the surface. Thus on sounding at great depths in the Mediterranean, Captains Berard and D'Urville have found that the cold does not increase in a high ratio as in the tropical regions of the ocean, the thermometer remaining fixed at about 55° F. between the depths of 1000 and 6000 feet. This might have been anticipated, as Captain Smyth in his survey had shown that the deepest part of the Straits of Gibraltar is only 1320 feet, so that a submarine barrier exists there which must prevent the influx of any under-current of the ocean cooled by polar ice.

Each of the four causes above mentioned, the wind, the tides, evaporation, and the expansion and contraction of water by heat and cold, may be conceived to operate independently of the others, and although the influence of all the rest were annihilated. But there is another cause, the rotation of the earth on its axis, which can only come into play when the waters have already been set in motion by some one or all of the forces above described, and when the direction of the

current so raised happens to be from south to north, or from north to south.

The principle on which this cause operates is probably familiar to the reader, as it has long been recognized in the case of the trade winds. Without enlarging, therefore, on the theory, it will be sufficient to offer an example of the mode of action alluded to. When a current flows from the Cape of Good Hope towards the Gulf of Guinea, it consists of a mass of water, which, on doubling the Cape, in lat. 35° , has a rotatory velocity of about 800 miles an hour; but when it reaches the line, it arrives at a parallel where the surface of the earth is whirled round at the rate of 1000 miles an hour, or about 200 miles faster.* If this great mass of water was transferred suddenly from the higher to the lower latitude, the deficiency of its rotatory motion, relatively to the land and water with which it would come into juxtaposition, would be such as to cause an apparent motion of the most rapid kind (of no less than 200 miles an hour) from east to west.

In the case of such a sudden transfer, the eastern coast of America, being carried round in an opposite direction, might strike against a large body of water with tremendous violence, and a considerable part of the continent might be submerged. This disturbance does not occur, because the water of the stream, as it advances gradually into new zones of the sea which are moving more rapidly, acquires by friction an accelerated velocity. Yet as this motion is not imparted instantaneously, the fluid is unable to keep up with the full speed of the new surface over which it is

* See a table in Capt. Hall's work before cited.

successively brought. Hence, to borrow the language of Herschel, when he speaks of the trade winds, "it lags or hangs back, in a direction opposite to the earth's rotation, that is from east to west *," and thus a current which would have run simply towards the north but for the rotation, may acquire a relative direction towards the west, or become a south-easterly current.

We may next consider a case where the circumstances are the converse of the above. The Gulf stream flowing from about lat. 20° is at first impressed with a velocity of rotation of about 940 miles an hour, and runs to the lat. 40° , where the earth revolves only at the rate of 766 miles, or 174 miles slower. In this case a relative motion of an opposite kind may result; and the current may retain an excess of rotatory velocity, tending continually to deflect it eastward.

Thus it will be seen that currents depend like the tides on no temporary or accidental circumstances, but on the laws which preside over the motions of the heavenly bodies. But although the sum of their influence in altering the surface of the earth may be very constant throughout successive epochs, yet the points where these operations are displayed in fullest energy shift perpetually. The height to which the tides rise, and the violence and velocity of currents, depend in a great measure on the actual configuration of the land, the contour of a long line of continental or insular coast, the depth and breadth of channels, the peculiar form of the bottom of seas — in a word, on a combination of circumstances which are made to vary continually by many igneous and aqueous causes,

* Treatise on Astronomy, chap. 3.

and, among the rest, by the tides and currents themselves. Although these agents, therefore, of decay and reproduction are local in reference to periods of short duration, such as those which history embraces, they are nevertheless universal, if we extend our views to a sufficient lapse of ages.

Destroying and transporting Power of Currents.—After these preliminary remarks on the nature and causes of currents, their velocity and direction, we may next consider their action on the solid materials of the earth. We shall find that their effects are, in many respects, strictly analogous to those of rivers. I have already treated, in the third chapter, of the manner in which currents sometimes combine with ice, in carrying mud, pebbles, and large fragments of rock to great distances. Their operations are more concealed from our view than those of rivers, but extend over wider areas, and are therefore of more geological importance.

Waste of the British Coasts.—Shetland Islands.—If we follow the eastern and southern shores of the British islands, from our Ultima Thule in Shetland to the Land's End in Cornwall, we shall find evidence of a series of changes since the historical era, very illustrative of the kind and degree of force exerted by tides and currents, co-operating with the waves of the sea. In this survey we shall have an opportunity of tracing their joint power on islands, promontories, bays, and estuaries; on bold, lofty cliffs, as well as on low shores; and on every description of rock and soil, from granite to blown sand.

The northernmost group of the British islands, the Shetland, are composed of a great variety of rocks, including granite, gneiss, mica-slate, serpentine, green-

stone, and many others, with some secondary rocks, chiefly sandstone and conglomerate. These islands are exposed continually to the uncontrolled violence of the Atlantic, for no land intervenes between their western shores and America. The prevalence, therefore, of strong westerly gales causes the waves to be sometimes driven with irresistible force upon the coast, while there is also a current setting from the north. The spray of the sea aids the decomposition of the rocks, and prepares them to be breached by the mechanical force of the waves. Steep cliffs are hollowed out into deep caves and lofty arches; and almost every promontory ends in a cluster of rocks, imitating the forms of columns, pinnacles, and obelisks.

Drifting of large Masses of Rock.—Modern observations show that the reduction of continuous tracts to such insular masses is a process in which nature is still actively engaged. “The Isle of Stenness,” says Dr. Hibbert, “presents a scene of unequalled desolation. In stormy winters, huge blocks of stones are overturned or are removed from their native beds, and hurried up a slight acclivity to a distance almost incredible. In the winter of 1802, a tabular-shaped mass, eight feet two inches by seven feet, and five feet one inch thick, was dislodged from its bed, and removed to a distance of from eighty to ninety feet. I measured the recent bed from which a block had been carried away the preceding winter (A. D. 1818), and found it to be seventeen feet and a half by seven feet, and the depth two feet eight inches. The removed mass had been borne to a distance of thirty feet, when it was shivered into thirteen or more lesser fragments, some of which were carried still farther, from 80 to 120 feet. A block, nine feet two inches by six feet

and a half, and four feet thick, was hurried up the acclivity to a distance of 150 feet."*

At Northmavine, also, angular blocks of stone have been removed in a similar manner to considerable distances by the waves of the sea, some of which are represented in the annexed figure.†

Fig. 18.



Stony fragments drifted by the sea. Northmavine, Shetland.

Effects of Lightning.—In addition to numerous examples of masses detached and driven by the waves, tides, and currents from their place, some remarkable effects of lightning are recorded in these isles. At Funzie, in Fetlar, about the middle of the last century, a rock of mica-schist, 105 feet long, ten feet broad, and in some places four feet thick, was in an instant torn by a flash of lightning from its bed, and broken into three large, and several smaller, fragments. One of

* Descrip. of Shetland Islands, p. 527. Edin. 1822.

† For this and the three following representations of rocks in the Shetland Isles, I am indebted to Dr. Hibbert's work before cited, which is rich in antiquarian and geological research.

these, twenty-six feet long, ten feet broad, and four feet thick, was simply turned over. The second, which was twenty-eight feet long, seventeen broad, and five feet in thickness, was hurled across a high point to the distance of fifty yards. Another broken mass, about forty feet long, was thrown still farther, but in the same direction, quite into the sea. There were also many smaller fragments scattered up and down.*

When we thus see electricity co-operating with the violent movements of the ocean in heaping up piles of shattered rocks on dry land, and beneath the waters, we cannot but admit that a region which shall be the theatre, for myriads of ages, of the action of such disturbing causes, might present, at some future period, if upraised far above the bosom of the deep, a scene of havoc and ruin that may compare with any now found by the geologist on the surface of our continents.

In some of the Shetland Isles, as on the west of Meikle Roe, dikes, or veins of soft granite, have mouldered away; while the matrix in which they were inclosed, being of the same substance, but of a firmer texture, has remained unaltered. Thus, long narrow ravines, sometimes twenty feet wide, are laid open, and often give access to the waves. After describing some huge cavernous apertures into which the sea flows for 250 feet in Roeness, Dr. Hibbert, writing in 1822, enumerates other ravages of the ocean. “A mass of rock, the average dimensions of which may perhaps be rated at twelve or thirteen feet square, and four and a half or five in thickness, was first moved from its bed, about fifty years ago, to a distance of thirty feet, and has since been twice turned over.”

* Dr. Hibbert, from MSS. of Rev. George Low, of Fetlar.

Passage forced by the sea through porphyritic rocks.— “ But the most sublime scene is where a mural pile of porphyry, escaping the process of disintegration that is devastating the coast, appears to have been left as a sort of rampart against the inroads of the ocean ; — the Atlantic, when provoked by wintry gales, batters against it with all the force of real artillery — the waves having, in their repeated assaults, forced themselves an entrance. This breach, named the Grind of the Navir (Fig. 19.), is widened every winter by the overwhelming surge that, finding a passage through it,

Fig. 19.



Grind of the Navir—Passage forced by the sea through rocks of hard porphyry.

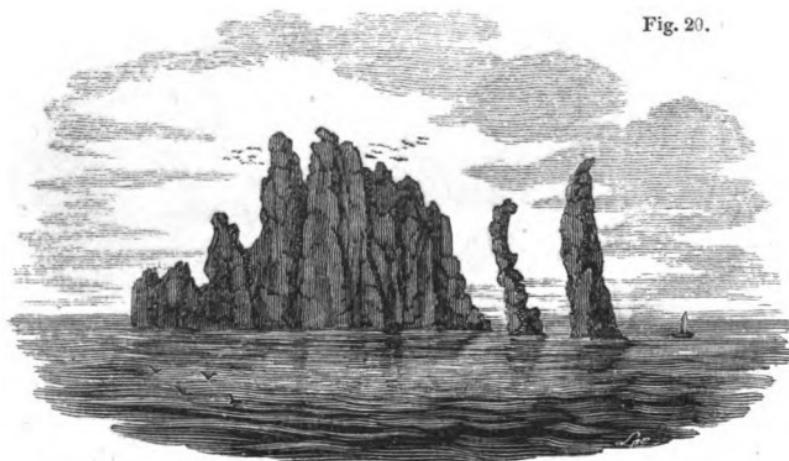
separates large stones from its sides, and forces them to a distance of no less than 180 feet. In two or three spots, the fragments which have been detached are brought together in immense heaps, that appear as an

accumulation of cubical masses, the product of some quarry."*

It is evident, from this example, that although the greater indestructibility of some rocks may enable them to withstand, for a longer time, the action of the elements, yet they cannot permanently resist. There are localities in Shetland, in which rocks of almost every variety of mineral composition are suffering disintegration; thus the sea makes great inroads on the clay slate of Fitfel Head, on the serpentine of the Vord Hill in Fetlar, and on the mica-schist of the Bay of Triesta, on the east coast of the same island, which decomposes into angular blocks. The quartz rock on the east of Walls, and the gneiss and mica-schist of Garthness, suffer the same fate.

Destruction of Islands.—Such devastation cannot be incessantly committed for thousands of years without dividing islands, until they become at last mere

Fig. 20.



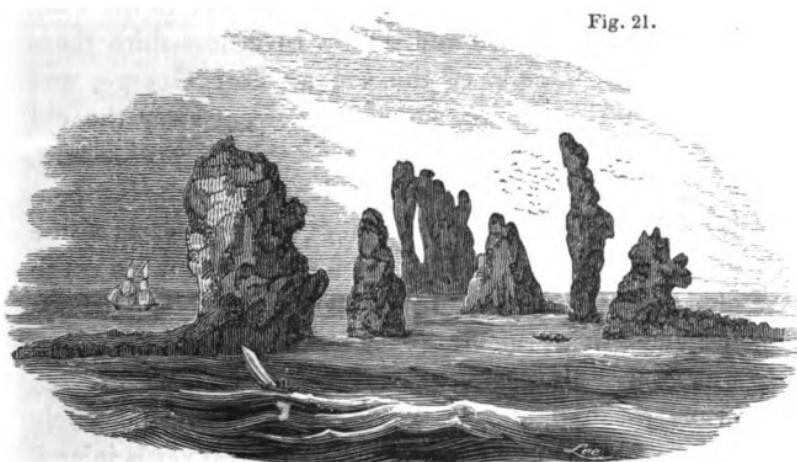
Granitic rocks named the Drongs, between Papa Stour and Hillswick Ness.

* Hibbert, p. 528.

clusters of rocks, the last shreds of masses once continuous. To this state many appear to have been reduced, and innumerable fantastic forms are assumed by rocks adjoining these islands, to which the name of Drongs is applied, as it is to those of similar shape in Feroe.

The granitic rocks (Fig. 20.) between Papa Stour and Hillswick Ness afford an example. A still more singular cluster of rocks is seen to the south of Hillswick Ness (Fig. 21.), which presents a variety of forms as viewed from different points, and has often been likened to a small fleet of vessels with spread sails.* We may imagine that in the course of time Hillswick

Fig. 21.



Granitic rocks to the south of Hillswick Ness, Shetland.

Ness itself may present a similar wreck, from the unequal decomposition of the rocks whereof it is composed, consisting of gneiss and mica-schist, traversed in all directions by veins of felspar-porphyrus.

* Hibbert, p. 519.

Midway between the groups of Shetland and Orkney is Fair Island, said to be composed of sandstone with high perpendicular cliffs. The current runs with such velocity, that during a calm, and when there is no swell, the rocks on its shores are white with the foam of the sea driven against them. The Orkneys, if carefully examined, would probably illustrate our present topic as much as the Shetland group. The north-east promontory of Sanda, one of these islands, has been cut off in modern times by the sea, so that it became what is now called Start Island, where a lighthouse was erected in 1807, since which time the new strait has grown broader.

East Coast of Scotland.—To pass over to the main land of Scotland, we find that in Inverness-shire there have been inroads of the sea at Fort George, and others in Morayshire, which have swept away the old town of Findhorn. On the coast of Kincardineshire, an illustration was afforded, at the close of the last century, of the effect of promontories in protecting a line of low-shore. The village of Mathers, two miles south of Johnshaven, was built on an ancient shingle beach, protected by a projecting ledge of limestone rock. This was quarried for lime to such an extent that the sea broke through, and in 1795 carried away the whole village in one night, and penetrated 150 yards inland, where it has maintained its ground ever since, the new village having been built farther inland on the new shore. In the Bay of Montrose, we find the North Esk and the South Esk rivers pouring annually into the sea large quantities of sand and pebbles, yet they have formed no deltas; for the waves aided by the current, setting across their mouths, sweep away all

the materials. Considerable beds of shingle, brought down by the North Esk, are seen along the beach.

Proceeding southwards, we learn that at Arbroath, in Forfarshire, which stands on a rock of red sandstone, gardens and houses have been carried away since the commencement of the present century by encroachments of the sea. It had become necessary before 1828 to remove the lighthouses, at the mouth of the estuary of the Tay, in the same county, at Button Ness, which were built on a tract of blown sand, the sea having encroached for three quarters of a mile.

Force of Waves and Currents in Estuaries.—The combined power which waves and currents can exert in *estuaries* (a term which I confine to bays entered both by rivers and the tides of the sea) was remarkably exhibited during the building of the Bell Rock Lighthouse, off the mouth of the Tay. The Bell Rock is a sunken reef, consisting of red sandstone, being from twelve to sixteen feet under the surface at high water, and about twelve miles from the mainland. At the distance of 100 yards, there is a depth, in all directions, of two or three fathoms at low water. In 1807, during the erection of the lighthouse, six large blocks of granite, which had been landed on the reef, were removed by the force of the sea, and thrown over a rising ledge to the distance of twelve or fifteen paces; and an anchor, weighing about 22 cwt., was thrown up upon the rock.* Mr. Stevenson informs us, moreover, that drift stones, measuring upwards of thirty cubic feet, or more than two tons weight, have, during storms, been often thrown upon the rock from the deep water.†

* Account of the Erection of the Bell Rock Lighthouse, p. 163.

† Ed. Phil. Journ. vol. iii. p. 54. 1820.

Submarine Forests.—Among the proofs that the sea has encroached on the land bordering the estuary of the Tay, Dr. Fleming has mentioned a submarine forest which has been traced for several miles along the northern shore of the county of Fife.* But subsequent surveys seem to have shown that the bed of peat containing tree-roots, leaves, and branches, now occurring at a lower level than the Tay, must have come into its present position by a general sinking of the ground on which the forest grew. The peat bed alluded to is not confined, says Mr. Buist, to the present channel of the Tay, but extends far beyond it, and is covered by stratified clay from fifteen to twenty-five feet in thickness, in the midst of which, in some places, is a bed full of sea-shells.† Recent discoveries having established the fact that upward and downward movements have affected our island since the general coast-line had nearly acquired its present shape, we must hesitate before we attribute any given change to a single cause, such as the local encroachment of the sea upon low land.

On the coast of Fife, at St. Andrew's, a tract of land, said to have intervened between the castle of Cardinal Beaton and the sea, has been entirely swept away, as were the last remains of the Priory of Crail, in the same county, in 1803. On both sides of the Frith of Forth, land has been consumed; at North Berwick in particular, and at Newhaven, where an arsenal and dock, built in the reign of James IV., in the fifteenth century, has been overflowed.

East Coast of England.—If we now proceed to the English coast, we find records of numerous lands hav-

* Quart. Journ. of Sci., &c., No. xxi. N. S. March, 1830.

† Buist, Quart. Journ. of Agricult., No. xlvi. p. 34. June, 1839.

ing been destroyed in Northumberland, as those near Bamborough and Holy Island, and at Tynemouth Castle, which now overhangs the sea, although formerly separated from it by a strip of land. At Hartlepool, and several other parts of the coast of Durham composed of magnesian limestone, the sea has made considerable inroads.

Coast of Yorkshire. — Almost the whole coast of Yorkshire, from the mouth of the Tees to that of the Humber, is in a state of gradual dilapidation. That part of the cliffs which consists of lias, the oolite series, and chalk, decays slowly. They present abrupt and naked precipices, often 300 feet in height; and it is only at a few points that the grassy covering of the sloping talus marks a temporary relaxation of the erosive action of the sea. The chalk cliffs are worn into caves and needles in the projecting headland of Flamborough, where they are decomposed by the salt spray, and slowly crumble away. But the waste is most rapid between that promontory and Spurn Point, or the coast of Holderness, as it is called, a tract consisting of beds of clay, gravel, sand, and chalk rubble. The irregular intermixture of the argillaceous beds causes many springs to be thrown out, and this facilitates the undermining process, the waves beating against them, and a strong current setting chiefly from the north. The wasteful action is very conspicuous at Dimlington Height, the loftiest point in Holderness, where the beacon stands on a cliff 146 feet above high water, the whole being composed of clay, with pebbles scattered through it.*

In the old maps of Yorkshire, we find spots, now

Phillips's Geology of Yorkshire, p. 61.

sand-banks in the sea, marked as the ancient sites of the towns and villages of Auburn, Hartburn, and Hyde. "Of Hyde," says Pennant, "only the tradition is left; and near the village of Hornsea, a street called Hornsea Beck has long since been swallowed." * Owthorne and its church have also been in great part destroyed, and the village of Kilnsea; but these places are now removed farther inland. The annual rate of encroachment at Owthorne for several years preceding 1830 is stated to have averaged about four yards.† Not unreasonable fears are entertained that at some future time the Spurn Point will become an island, and that the ocean, entering into the estuary of the Humber, will cause great devastation. ‡ Pennant, after speaking of the silting up of some ancient ports in that estuary, observes, "But, in return, the sea has made most ample reprisals; the site, and even the very names of several places, once towns of note upon the Humber, are now only recorded in history; and Ravensper was at one time a rival to Hull (Madox, *Ant. Exch.* i. 422.), and a port so very considerable in 1332, that Edward Baliol and the confederated English Barons sailed from hence to invade Scotland; and Henry IV., in 1399, made choice of this port to land at, to effect the deposition of Richard II.; yet the whole of this has long since been devoured by the merciless ocean: extensive sands, dry at low water, are to be seen in their stead." §

Pennant describes Spurn Head as a promontory in the form of a sickle, and says the land, for some miles

* *Arctic Zoology*, vol. i. p. 10. Introduction.

† For this information I am indebted to Mr. Phillips of York.

‡ Phillips's *Geology of Yorkshire*, p. 60.

§ *Arct. Zool.* vol. i. p. 13. Introduction.

to the north, was "perpetually preyed on by the fury of the German Sea, which devours whole acres at a time, and exposes on the shores considerable quantities of beautiful amber."*

According to Bergmann, a strip of land, with several villages, was carried away near the mouth of the Humber in 1475.

Lincolnshire.—The maritime district of Lincolnshire consists chiefly of lands that lie below the level of the sea, being protected by embankments. Great parts of this fenny tract were, at some unknown period, a woody country, but were afterwards inundated, and are now again recovered from the sea. Some of the fens were embanked and drained by the Romans; but after their departure the sea returned, and large tracts were covered with beds of silt containing marine shells, now again converted into productive lands. Many dreadful catastrophes are recorded by incursions of the sea, whereby several parishes have been at different times overwhelmed.

It has been lately proposed by Sir John Rennie and others to rescue from the dominion of the sea a large part of what is called "the Wash," between the counties of Lincoln and Norfolk. The plan for accomplishing this object consists in deepening and straightening the channels of the rivers Ouse, Nene, Witham, and Welland, all of which are to be confined between well-formed banks, and united into one grand channel in the centre of the Wash. The land already gained by similar operations since the middle of the seventeenth century is of vast extent, and the additional space which the projectors hope to reclaim on the opposite

* Arct. Zool. vol. i. p. 18. Introduction.

shores of Lincoln and Norfolk will amount to 150,000 acres, and be half as large again as the county of Rutland in area.*

So great is the quantity of mud suspended in the tidal waters of the rivers entering the Wash, that the accumulation of soil by "warping," wherever the force of the winds and currents can be checked, is surprisingly rapid. Thus, for example, when a portion of the old channel of the Ouse, containing 800 acres, was deserted by an alteration of the drainage, it was warped up, without any artificial aid, to the height of twenty-five feet in five or six years.†

Norfolk.—We come next to the cliffs of Norfolk and Suffolk, where the decay is in general incessant and rapid. At Hunstanton, on the north, the undermining of the lower arenaceous beds at the foot of the cliff causes masses of red and white chalk to be precipitated from above. Between Hunstanton and Weybourne, low hills, or dunes, of blown sand, are formed along the shore, from fifty to sixty feet high. They are composed of dry sand, bound in a compact mass by the long creeping roots of the plant called Marram (*Arundo arenaria*). Such is the present set of the tides, that the harbours of Clay, Wells, and other places, are securely defended by these barriers; affording a clear proof that it is not the strength of the material at particular points that determines whether the sea shall be progressive or stationary, but the general contour of the coast.

The waves constantly undermine the low chalk cliffs, covered with sand and clay, between Weybourne and

* Sir J. Rennie, Report on River Ouse Outfall Improvement, p. 13. July, 1839.

† Ibid. p. 9.

Sheringham, a certain portion of them being annually removed. At the latter town I ascertained, in 1829, some facts which throw light on the rate at which the sea gains upon the land. It was computed, when the present inn was built, in 1805, that it would require seventy years for the sea to reach the spot : the mean loss of land being calculated, from previous observations, to be somewhat less than one yard annually. The distance between the house and the sea was fifty yards ; but no allowance was made for the slope of the ground being *from* the sea, in consequence of which, the waste was naturally accelerated every year, as the cliff grew lower, there being at each succeeding period less matter to remove when portions of equal area fell down. Between the years 1824 and 1829, no less than seventeen yards were swept away, and only a small garden was then left between the building and the sea. There was in 1829, a depth of twenty feet (sufficient to float a frigate) at one point in the harbour of that port, where, only forty-eight years before, there stood a cliff fifty feet high, with houses upon it ! If once in half a century an equal amount of change were produced suddenly by the momentary shock of an earthquake, history would be filled with records of such wonderful revolutions of the earth's surface ; but, if the conversion of high land into deep sea be gradual, it excites only local attention. The flag-staff of the Preventive Service station, on the south side of this harbour, was thrice removed inland between the years 1814 and 1829, in consequence of the advance of the sea.

Farther to the south we find cliffs, composed, like those of Holderness before mentioned, of alternating strata of blue clay, gravel, loam, and fine sand. Al-

though they sometimes exceed 300 feet in height, the havoc made on the coast is most formidable. The whole site of ancient Cromer now forms part of the German Ocean, the inhabitants having gradually retreated inland to their present situation, from whence the sea still threatens to dislodge them. In the winter of 1825, a fallen mass was precipitated from near the lighthouse, which covered twelve acres, extending far into the sea, the cliffs being 250 feet in height.* The undermining by springs has sometimes caused large portions of the upper part of the cliffs, with houses still standing upon them, to give way, so that it is impossible, by erecting breakwaters at the base of the cliffs, permanently to ward off the danger.

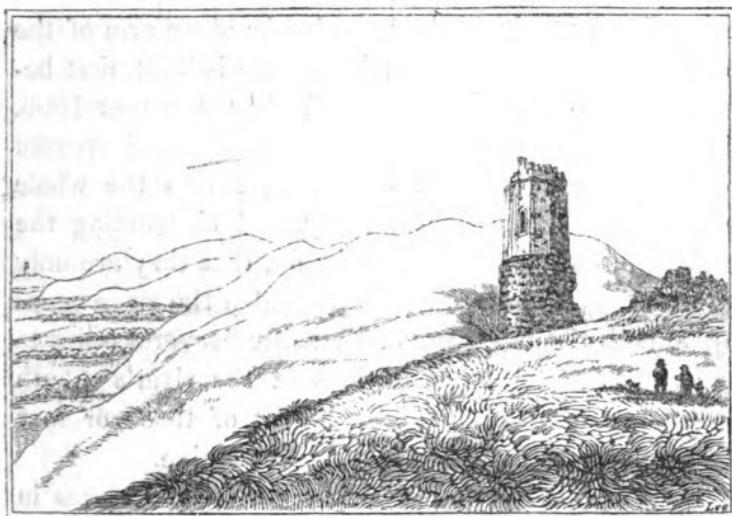
On the same coast, says Mr. R. C. Taylor, the ancient villages of Shipden, Wimpwell, and Eccles have disappeared; several manors and large portions of neighbouring parishes having, piece after piece, been swallowed up; nor has there been any intermission, from time immemorial, in the ravages of the sea along a line of coast twenty miles in length, in which these places stood.† Of Eccles, however, a monument still remains in the ruined tower of the old church, which is half buried in the dunes of sand within a few paces (60?) of the sea-beach (fig. 22.). So early as 1605 the inhabitants petitioned James I. for a reduction of taxes, as 300 acres of land, and all their houses, save fourteen, had then been destroyed by the sea. Not one half that number of acres now remains in the parish, and hills of blown sand now occupy the site of the houses which were still extant in 1605. When I visited the spot in 1839, the sea was

* Taylor's Geology of East Norfolk, p. 32.

† Ibid.

fast encroaching on the sandhills, and had lain open on the beach the foundations of a house fourteen yards square, the upper part of which had evidently been pulled down before it had been buried under sand. The body of the church has also been long buried, but the tower still remains visible.

Fig. 22.

*Tower of the buried Church of Eccles, Norfolk.*

The inland slope of the hills of blown sand, is shown in this view, with the lighthouse of Hasborough in the distance.

Hills of blown sand, between Eccles and Winterton, have barred up and excluded the tide for many hundred years from the mouths of several small estuaries ; but there are records of nine breaches, from 20 to 120 yards wide, having been made through these, by which immense damage was done to the low grounds in the interior. A few miles south of Happisburgh, also, are hills of blown sand, which extend to Yarmouth. These *dunes* afford a temporary protection to the coast, and

an inland cliff about a mile long, at Winterton, shows clearly that at that point the sea must have penetrated formerly farther than at present

Silting up of Estuaries.—At Yarmouth, the sea has not advanced upon the sands in the slightest degree since the reign of Elizabeth. In the time of the Saxons, a great estuary extended as far as Norwich, which city is represented, even in the thirteenth and fourteenth centuries, as “situated on the banks of an arm of the sea.” The sands whereon Yarmouth is built, first became firm and habitable ground about the year 1008, from which time a line of dunes has gradually increased in height and breadth, stretching across the whole entrance of the ancient estuary, and obstructing the ingress of the tides so completely, that they are only admitted by the narrow passage which the river keeps open, and which has gradually shifted several miles to the south. The ordinary tides at the river’s mouth rise, at present, only to the height of three or four feet, the spring tides to about eight or nine.

By the exclusion of the sea, thousands of acres in the interior have become cultivated lands; and, exclusive of smaller pools, upwards of sixty fresh-water lakes have been formed, varying in depth from fifteen to thirty feet, and in extent from one acre to twelve hundred.* The Yare, and other rivers, frequently communicate with these sheets of water; and thus they are liable to be filled up gradually with lacustrine and fluviatile deposits, and to be converted into land covered with forests. Yet it must not be imagined, that the acquisition of new land fit for cultivation in Norfolk and Suffolk indicates any permanent growth

* Taylor’s Geology of East Norfolk, p. 10.

of the eastern limits of our island, to compensate its reiterated losses. No *delta* can form on such a shore.

Immediately off Yarmouth, and parallel to the shore, is a great range of sand-banks, the shape of which varies slowly from year to year, and often suddenly after great storms. Captain Hewett, R. N., found in these banks, in 1836, a broad channel sixty-five feet deep, where there was only a depth of four feet during a prior survey in 1822. The sea had excavated to the depth of sixty feet in the course of fourteen years, or perhaps a shorter period. The new channel thus formed serves at present (1838), for the entrance of ships into Yarmouth Roads ; and the magnitude of this change shows how easily a new set of the waves and currents might endanger the submergence of the land gained within the ancient estuary of the Yare.

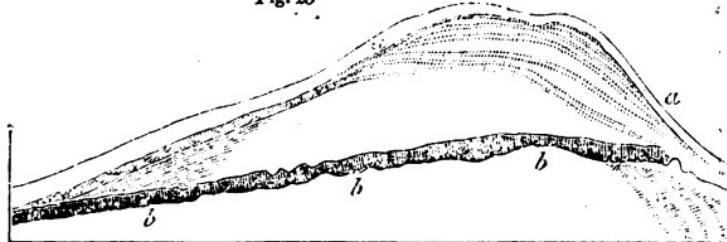
That great banks should be thrown across the mouths of estuaries on our eastern coast, where there is not a large body of river-water to maintain an open channel, is perfectly intelligible, when we bear in mind that the marine current, sweeping along the coast, is charged with the materials of wasting cliffs, and ready to form a bar anywhere, the instant its course is interrupted or checked by any opposing stream. The mouth of the Yare has been, within the last five centuries, diverted about four miles to the south. In like manner it is evident that at some remote period, the river Alde entered the sea at Aldborough, until its ancient outlet was barred up and at length transferred to a point no less than ten miles distant to the south-west. In this case, ridges of sand and shingle, like those of Lowestoff Ness, which will be described by-and-by, have been thrown up between the river and the sea ; and an ancient sea-cliff is to be seen, now inland.

It may be asked why the rivers on our east coast are always deflected southwards, although the tidal current flows alternately from the south and north? The cause is to be found in the superior force of what is commonly called “the flood tide from the north,” a tidal wave derived from the Atlantic, a small part of which passes eastward up the English Channel, and through the Straits of Dover and then northwards, while the principal body of water, moving much more rapidly in a more open sea, on the western side of Britain, first passes the Orkneys, and then turning, flows down between Norway and Scotland, and sweeps with great velocity along our eastern coast. It is well known that the highest tides on this coast are occasioned by a powerful north-west wind which raises the eastern part of the Atlantic, and causes it to pour a greater volume of water into the German ocean. This circumstance of a violent *off-shore* wind being attended with a rise of the waters, instead of a general retreat of the sea, naturally excites the wonder of the inhabitants of our coast. In many districts they look with confidence for a rich harvest of that valuable manure, the sea-weed, when the north-westerly gales prevail, and are rarely disappointed. The phenomenon is so well calculated to awaken curiosity, that I have heard the cause discussed by peasants and fishermen; and more than once they have hazarded a theory of their own to account for it. The most ingenious idea which I heard suggested was this: a vast body of surface water, say they, is repelled by the wind from the shore, which afterwards returns, in order to restore the level of the sea; by this means a strong under-current is produced, which tears up the weed from the bed of the sea, and casts it ashore. The true explanation,

however, of the phenomenon is doubtless that above mentioned.

Coast of Suffolk.—The cliffs of Suffolk, to which we next proceed, are somewhat less elevated than those of Norfolk, but composed of similar alternations of clay, sand, and gravel. From Gorleston in Suffolk, to within a few miles north of Lowestoff, the cliffs are slowly undermined. Near the last-mentioned town, there is an inland cliff about sixty feet high, the sloping talus of which is covered with turf and heath.

Fig. 23

*Map of Lowestoff Ness, Suffolk. **

- a, a. The dotted lines express a series of sand and shingle, forming the extremity of the triangular space called the Ness.
- b, b, b. The dark line represents the inland cliff on which the town of Lowestoff stands, between which and the sea is the Ness.

Between the cliff and the sea is a low, flat tract of sand, called the Ness, nearly three miles long, and for the most part out of reach of the highest tides. The point of the Ness projects from the base of the original cliff to the distance of 660 yards. This accession of land, says Mr. Taylor, has been effected at distinct and distant intervals, by the influence of currents running between the land and a shoal about a mile off Lowestoff, called the Holm Sand. The lines of growth in

* From Mr. R. C. Taylor's Mem., see below.

the Ness are indicated by a series of concentric ridges or embankments inclosing limited areas, and several of these ridges have been formed within the observation of persons now living. A rampart of heavy materials is first thrown up to an unusual altitude by some extraordinary tide, attended with a violent gale. Subsequent tides extend the base of this high bank of shingle, and the interstices are then filled with sand blown from the beach. The Arundo and other marine plants by degrees obtain a footing ; and creeping along the ridge, give solidity to the mass, and form in some cases a matted covering of turf. Meanwhile another mound is forming externally, which by the like process rises and gives protection to the first. If the sea forces its way through one of the external and incomplete mounds, the breach is soon repaired. After a while the marine plants within the areas inclosed by these embankments are succeeded by a better species of herbage, affording good pasturage, and the sands become sufficiently firm to support buildings.*

Destruction of Dunwich by the Sea.—The sea undermines the high cliffs near Corton, a few miles north of Lowestoff, as also two miles south of the same town, at Pakefield, a village which has been in part swept away during the present century. From thence to Dunwich the destruction is constant. At the distance of 250 yards from the wasting cliff at Pakefield, where we must suppose land to have existed at no remote period, the sea is sixteen feet deep at low water, and in the roadstead beyond, twenty-four feet. Of the gradual destruction of Dunwich, once the most

* The formation of the Ness is well described by Mr. R. C. Taylor, Phil. Mag., Oct. 1827, p. 297.

considerable seaport on this coast, we have many authentic records. Gardner, in his history of that borough, published in 1754, shows, by reference to documents beginning with Doomsday Book, that the cliffs at Dunwich, Southwold, Eastern, and Pakefield, have been always subject to wear away. At Dunwich, in particular, two tracts of land which had been taxed in the eleventh century, in the time of King Edward the Confessor, are mentioned, in the Conqueror's survey, made but a few years afterwards, as having been devoured by the sea. The losses, at a subsequent period, of a monastery,—at another of several churches,—afterwards of the old port,—then of four hundred houses at once,—of the church of St. Leonard, the high road, town-hall, gaol, and many other buildings, are mentioned, with the dates when they perished. It is stated that, in the sixteenth century, not one quarter of the town was left standing; yet the inhabitants retreating inland, the name was preserved, as has been the case with many other ports, when their ancient site has been blotted out. There is, however, a church, of considerable antiquity, still standing, the last of twelve mentioned in some records. In 1740, the laying open of the churchyard of St. Nicholas and St. Francis, in the sea-cliffs, is well described by Gardner, with the coffins and skeletons exposed to view — some lying on the beach, and rocked —

“In cradle of the rude imperious surge.”

Of these cemeteries no remains can now be seen. Ray also says, “that ancient writings make mention of a wood a mile and a half to the east of Dunwich, the site of which must at present be so far within the sea.” *

* Consequences of the Deluge, Phys. Theol. Discourses,

This city, once so flourishing and populous, is now a small village, with about twenty houses, and one hundred inhabitants.

There is an old tradition, “that the tailors sat in their shops at Dunwich, and saw the ships in Yarmouth Bay;” but when we consider how far the coast at Lowestoff Ness projects between these places, we cannot give credit to the tale, which, nevertheless, proves how much the inroads of the sea in times of old had prompted men of lively imagination to indulge their taste for the marvellous.

Gardner’s description of the cemeteries laid open by the waves remind us of the scene which has been so well depicted by Bewick*, and of which numerous points on the same coast might have suggested the idea. On the verge of a cliff, which the sea has undermined, are represented the unshaken tower and western end of an abbey. The eastern aisle is gone, and the pillars of the cloister are soon to follow. The waves have almost isolated the promontory, and invaded the cemetery, where they have made sport with the mortal relics, and thrown up a skull upon the beach. In the foreground is seen a broken tombstone, erected, as its legend tells, “to perpetuate the memory of one whose name is obliterated, as is that of the county for which he was ‘Custos Rotulorum.’” A cormorant is perched on the monument, defiling it, as if to remind some moraliser, like Hamlet, of “the base uses” to which things sacred may be turned. Had this excellent artist desired to satirise certain popular theories of geology, he might have inscribed the stone to the memory of some philosopher who taught “the permanency of

* History of British Birds, vol. ii. p. 220. Ed. 1821.

existing continents" — "the era of repose" — "the impotence of modern causes."

The incursions of the sea at Aldborough were formerly very destructive, and this borough is known to have been once situated a quarter of a mile east of the present shore. The inhabitants continued to build farther inland, till they arrived at the extremity of their property, and then the town decayed greatly; but two sand-banks, thrown up at a short distance, now afford a temporary safeguard to the coast. Between these banks and the present shore, where the current now flows, the sea is twenty-four feet deep on the spot where the town formerly stood.

Continuing our survey of the Suffolk coast to the southward, we find that the cliffs of Bawdsey and Felixtow are foundering continually. It appears that, within the memory of persons now living, the Orwell river continued its course in a more direct line to the sea, and entered to the north instead of the south of the low bank on which Landguard Fort is built.

Essex. — Harwich is said to have owed its rise to the destruction of Orwell, a town which stood on the spot now called "the west rocks," and was overwhelmed by an inroad of the sea since the Conquest. The isthmus on which Harwich stands will probably become an island in about half a century, for the sea by that time may have made a breach near Lower Dover Court, where the cliffs are composed of horizontal beds of London clay containing septaria. They had wasted away considerably between the years 1829 and 1838, at both which periods I examined this coast. In that short interval several gardens and many houses had been swept into the sea, and in April 1838, a whole street was threatened with destruction. The advance

of the sea is much accelerated by the traffic carried on in septaria, which are shipped off to Harwich for cement as fast as they fall down upon the beach, where they become the property of the lord of the manor, who is not lord of the soil on which the buildings stand. These stones, if allowed to remain in heaps on the shore, would break the force of the waves, and retard the conversion of the isthmus into an island, an event which might be followed by the destruction of the town of Harwich.

Among other losses it is recorded, that since the year 1807, a field called the Vicar's Field, which belonged to the living of Harwich, has been overwhelmed *; and in the year 1820 there was a considerable space between the battery at Harwich, built in the beginning of the present century, and the sea; part of the fortification had been swept away in 1829, and the rest then overhung the water.

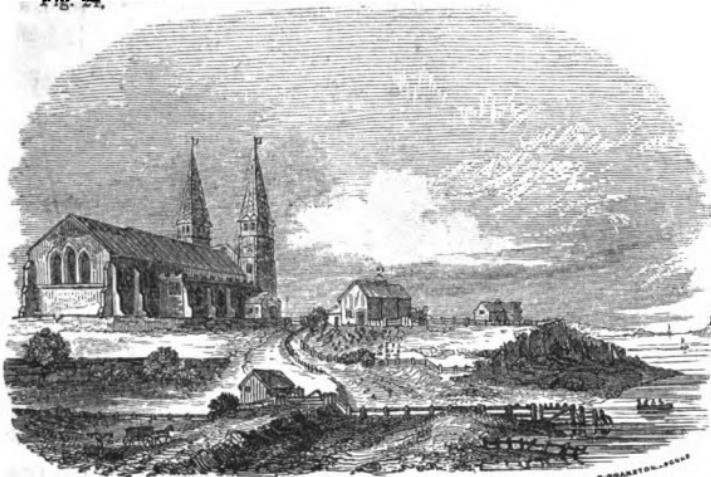
At Walton Naze, in the same county, the cliffs, composed of London clay, capped by the shelly sands of the crag, reach the height of about 100 feet, and are annually undermined by the waves. The old churchyard of Walton has been washed away, and the cliffs to the south are constantly disappearing.

Kent. — Isle of Sheppey. — On the coast bounding the estuary of the Thames, there are numerous examples both of the gain and loss of land. The Isle of Sheppey, which is now about six miles long by four in breadth, is composed of London clay. The cliffs on the north, which are from sixty to eighty feet high, decay rapidly, fifty acres having been lost in twenty years, between 1810 and 1830. The church at Minster, now near the coast, is said to have been in the middle of

* On authority of Dr. Mitchell, F. G. S.

the island in 1780 * ; and it has been conjectured that, at the present rate of destruction, the whole isle will be annihilated in about half a century. On the coast of the mainland to the east of Sheppey is Herne Bay ; a place still retaining the name of a bay, although it is no longer appropriate, as the waves and currents have swept away the ancient headlands. There was formerly a small promontory in the line of the shoals where the present pier is built, by which the larger bay was divided into two, called the Upper and Lower.†

Fig. 24.

*View of Reculver Church, taken in the year 1781.*

1. Isle of Sheppey.
2. Ancient chapel now destroyed. The cottage between this chapel and the cliff was demolished by the sea, in 1782.

Still farther east stands the church of Reculver, upon a cliff composed of clay and sand, about twenty feet high. Reculver (Regulvium) was an important military station in the time of the Romans, and appears, from Leland's account, to have been, so late as Henry

* For this information I am indebted to W. Gunnell, Esq.

† On the authority of W. Richardson, Esq., F.G.S.

Fig. 25.

*Reculver Church, in 1834.*

VIII.'s reign, nearly one mile distant from the sea. In the "Gentleman's Magazine," there is a view of it, taken in 1781, which still represents a considerable space as intervening between the north wall of the churchyard and the cliff.* Some time before the year 1780, the waves had reached the site of the ancient Roman camp, or fortification, the walls of which had continued for several years after they were undermined to overhang the sea, being firmly cemented into one mass. They were eighty yards nearer the sea than the church, and they are spoken of in the "Topographica Britannica," in the year 1780, as having recently fallen down. In 1804, part of the

* Vol. ii. New Series, 1809, p. 801.

churchyard with some adjoining houses was washed away, and the ancient church, with its two lofty spires, a well known land-mark, was dismantled and abandoned as a place of worship. It is still standing (1834), but would probably have been annihilated ere this, had not the force of the waves been checked by an artificial causeway of stones and large wooden piles driven into the sands to break the force of the waves.*

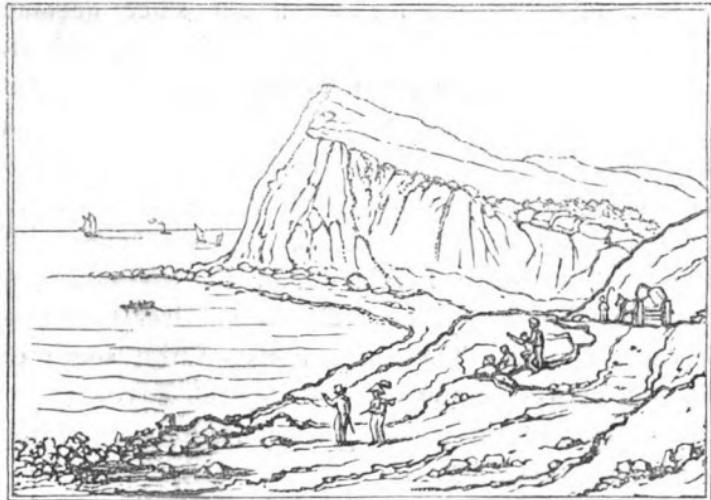
Isle of Thanet. — The isle of Thanet was, in the time of the Romans, separated from the rest of Kent by a navigable channel, through which the Roman fleets sailed on their way to and from London. Bede describes this small estuary as being, in the beginning of the eighth century, three furlongs in breadth; and it is supposed that it began to grow shallow about the period of the Norman conquest. It was so far silted up in the year 1485, that an act was then obtained to build a bridge across it; and it has since become marsh land with small streams running through it. On the coast, Bedlam Farm, belonging to the hospital of that name, lost eight acres in the twenty years preceding 1830, the land being composed of chalk from forty to fifty feet above the level of the sea. It has been computed, that the average waste of the cliff between the North Foreland and the Reculvers, a distance of about eleven miles, is not less than two feet per annum. The chalk cliffs on the south of Thanet, between Ramsgate and Pegwell Bay, have on an average lost three feet per annum for the ten last years (preceding 1830).

Goodwin Sands. — The Goodwin Sands lie opposite this part of the Kentish coast. They are about ten miles in length, and are in some parts three, and, in

* Dr. Mitchell, *Proceedings of Geol. Soc.* vol. ii. No. 1.

others seven miles distant from the shore ; and, for a certain space, are laid bare at low water. That they are a remnant of land, and not "a mere accumulation of sea sand," as Rennell imagined *, may be presumed from the fact that, when the erection of a lighthouse on this shoal was in contemplation by the Trinity Board in the year 1817, it was found, by borings, that the bank consisted of fifteen feet of sand, resting on blue clay. An obscure tradition has come down to us, that the estates of Earl Goodwin, the father of Harold, who died in the year 1053, were situated here, and some have conjectured that they were overwhelmed by the flood mentioned in the Saxon chronicle, *sub anno* 1099. The last remains of an island, consisting, like Sheppey, of clay, may perhaps have been carried away about that time.

Fig. 26.



Shakspeare's Cliff in 1836, seen from the North-east.

There are other records of waste in the county of Kent, as at Deal ; and at Dover, where Shakspeare's

* Geog. of Herod. vol. ii. p. 326.

cliff, composed entirely of chalk, has suffered greatly, and continually diminishes in height, the slope of the hill being towards the land. (See fig. 26.) There was an immense landslip from this cliff in 1810, by which Dover was shaken as if by an earthquake, and a still greater one in 1772.* We may suppose, therefore, that the view from the top of the precipice in the year 1600, when the tragedy of King Lear was written, was more "fearful and dizzy" than it is now.

Straits of Dover.—In proceeding from the northern parts of the German Ocean towards the Straits of Dover, the water becomes gradually more shallow, so that in the distance of about two hundred leagues we pass from a depth of 120, to that of 58, 38, 18, and even less than 2 fathoms. The shallowest part follows a line drawn between Romney Marsh and Boulogne. From this point the English Channel again deepens progressively as we proceed westward, so that the Straits of Dover may be said to part two seas.†

Whether England was formerly united with France has often been a favourite subject of speculation. So early as 1605 our countryman Verstegan, in his "Antiquities of the English Nation," observed that many preceding writers had maintained this opinion, but without supporting it by any weighty reasons. He accordingly endeavours himself to confirm it by various arguments, the principal of which are, first, the proximity and identity of the composition of the opposite cliffs and shores of Albion and Gallia, which, whether flat and sandy or steep and chalky, correspond exactly with each other; secondly, the occurrence of

* Dodsley's Ann. Regist. 1772.

† Stevenson, Ed. Phil. Journ. No. v. p. 45., and Dr. Fitton, Geol. Trans., 2d series, vol. iv. plate 9.

a submarine ridge, called “our Lady’s Sands,” extending from shore to shore at no great depth, and which from its composition appears to be the original basis of the isthmus; thirdly, the identity of the noxious animals in France and England, which could neither have swum across, nor have been introduced by man. Thus no one, he says, would have imported wolves, therefore “these wicked beasts did of themselves pass over.”

He supposes the ancient isthmus to have been about six English miles in breadth, composed entirely of chalk and flint, and in some places of no great height above the sea-level. He does not pretend to decide whether the first breach was made by an earthquake, the channel having afterwards been enlarged by the waves, or whether it was cut by the labour of man for a commodious passage, or means of defence, or whether it was occasioned by the gradual encroachments of the sea, which he imagines to have been higher, and to have run with a stronger current on the north-eastern than on the western side of the isthmus.

Cuvier informs us that in 1753 (a century and a half later), a society at Amiens proposed the question above alluded to as a prize essay, which was gained by the celebrated Desmarest, then a young man. With respect to this essay, it has been justly remarked, in a recent memoir by Mr. Page, that Desmarest borrowed all his arguments from Verstegan, for they are not only the same in number and substance, but are advanced in precisely the same order.*

* See paper read by Mr. Page to Lit. and Phil. Soc. of St. Andrews, Fife Journal, Jan. 17. 1839, and Cuvier’s *Eloge de Desmarest*.

When we consider the state of physical science at the commencement of the seventeenth century, we cannot too much admire the philosophical spirit and acuteness with which Verstegan conducts his argument. The operation of the waves and tides, he says, would have been more powerful when the straits were narrower than now, when they are still destroying cliffs composed of similar materials. He suggests the possible cooperation of earthquakes; and I may mention that there are geological appearances at the base of the cliffs near Dover and Brighton, which indicate oscillations in the relative level of sea and land at a very modern period. We there learn that the chalk itself, originally a marine deposit, has been depressed about 60 feet since its first emergence from the deep, and that the actual cliffs are not the first which have been excavated. These, and perhaps other upward and downward movements, may have taken place as slowly as those now in progress in Sweden and Greenland, and they cannot fail to have greatly assisted the denuding force of “the ocean stream.”

Ποταμοῦ μεγὰ σθένος Ωκεανοῦ.

Folkstone. — At Folkstone, the sea undermines the chalk and subjacent strata. About the year 1716 there was a remarkable sinking of a tract of land near the sea, so that houses became visible from certain points at sea, and from particular spots on the sea cliffs, from whence they could not be seen previously. In the description of this subsidence in the Phil. Trans. 1716, it is said, “that the land consisted of a solid stony mass (chalk), resting on wet clay (gault), so that it slid forwards towards the sea, just as a ship is launched on tallowed planks.” It is also stated that, within the

memory of persons then living, the cliff there had been washed away to the extent of ten rods.

Encroachments of the sea at Hythe are also on record; but between this point and Rye there has been a gain of land within the times of history; the rich level tract called Romney Marsh, or Dungeness, about ten miles in width and five in breadth, and formed of silt, having received great accession. It has been necessary, however, to protect it from the sea, from the earliest periods, by embankments, the towns of Lydd and Romney being the only parts of the marsh above the level of the highest tides.* These additions of land are exactly opposite that part of the English Channel where the conflicting tide-waves from the north and south meet; for, as that from the north is, for reasons already explained, the most powerful, they do not neutralize each other's force till they arrive at this distance from the Straits of Dover. Here therefore some portion of the materials drifted from west to east along the shores of Sussex and Kent find at length a resting place.

Rye, situated to the south of Romney marsh, was once destroyed by the sea, but it is now two miles distant from it. The neighbouring town of Winchelsea was destroyed in the reign of Edward I., the mouth of the Rother stopped up, and the river diverted into another channel. In its old bed, an ancient vessel, apparently a Dutch merchantman, was recently found. It was built entirely of oak, and much blackened.† Large quantities of hazel nuts, peat, and wood are found in digging in Romney marsh.

* On the authority of Mr. J. Meryon, of Rye.

† Edin. Journ. of Sci., No. xix. p. 56.

South Coast of England.—To pass over some points near Hastings, where the cliffs have wasted at several periods, we arrive at the promontory of Beachy Head. Here a mass of chalk, three hundred feet in length, and from seventy to eighty in breadth, fell, in the year 1813, with a tremendous crash; and similar slips have since been frequent.*

About a mile to the west of the town of Newhaven the remains of an ancient entrenchment are seen on the brow of Castle Hill. This earth-work, supposed to be Roman, was evidently once of considerable extent and of an oval form, but the greater part has been cut away by the sea. The cliffs, which are undermined here, are high; more than one hundred feet of chalk being covered by tertiary clay and sand, from sixty to seventy feet in thickness. In a few centuries the last vestiges of the plastic clay formation on the southern borders of the chalk of the South Downs on this coast will be annihilated, and future geologists will learn, from historical documents, the ancient geographical boundaries of this group of strata in that direction. On the opposite side of the estuary of the Ouse, on the east of Newhaven harbour, a bed of shingle, composed of chalk flints, derived from the waste of the adjoining cliffs, had accumulated at Seaford for several centuries. In the great storm of November, 1824, this bank was entirely swept away, and the town of Seaford inundated. Another great beach of shingle is now forming from fresh materials.

The whole coast of Sussex has been incessantly encroached upon by the sea from time immemorial; and, although sudden inundations only, which over-

* Webster, Geol. Trans., vol. ii. p. 192. 1st. series.

whelmed fertile or inhabited tracts, are noticed in history, the records attest an extraordinary amount of loss. During a period of no more than eighty years, there are notices of about *twenty* inroads, in which tracts of land of from twenty to *four hundred acres* in extent were overwhelmed at once; the value of the tithes being mentioned by Nicholas, in his *Taxatio Ecclesiastica*.* In the reign of Elizabeth, the town of Brighton was situated on that tract where the chain pier now extends into the sea. In the year 1665 twenty-two tenements had been destroyed under the cliff. At that period there still remained under the cliff 113 tenements, the whole of which were overwhelmed in 1703 and 1705. No traces of the ancient town are now perceptible, yet there is evidence that the sea has merely resumed its ancient position at the base of the cliffs, the site of the old town having been merely a beach abandoned by the ocean for ages.

Hampshire—Isle of Wight.—It would be endless to allude to all the localities on the Sussex and Hampshire coasts where the land has given way; but I may point out the relation which the geological structure of the Isle of Wight bears to its present shape, as attesting that the coast owes its outline to the continued action of the sea. Through the middle of the island runs a high ridge of chalk strata, in a vertical position, and in a direction east and west. This chalk forms the projecting promontory of Culver Cliff on the east, and of the Needles on the west; while Sandown Bay on the one side, and Compton Bay on the other, have been hollowed out of the softer

* Mantell, *Geology of Sussex*, p. 293.

sands and argillaceous strata, which are inferior, in geological position, to the chalk.

The same phenomena are repeated in the Isle of Purbeck, where the line of vertical chalk forms the projecting promontory of Handfast Point; and Swanage Bay marks the deep excavation made by the waves in the softer strata, corresponding to those of Sandown Bay.

Hurst Castle bank — progressive motion of sea-beaches.— Although the loose pebbles and grains of sand composing any given line of sea-beach are carried sometimes one way sometimes another, they have, nevertheless, an ultimate motion in one particular direction.* Their progress, for example, on the south coast of England is from west to east, which is owing partly to the action of the waves driven eastwards by the prevailing wind, and partly to the current, or the motion of the general body of water caused by the tides and winds. The force of the waves gives motion to pebbles which the velocity of the currents alone would be unable to carry forwards; but as the pebbles are finally reduced to sand or mud, by continual attrition, they are brought within the influence of a current; and this cause must determine the course which the the main body of matter derived from wasting cliffs will eventually take.

It appears, from the observations of Mr. Palmer and others, that if a pier or groin be erected anywhere on our southern or south-eastern coast to stop the progress of the beach, a heap of shingle soon collects on the western side of such artificial barriers. The pebbles continue to accumulate till they rise as high as the pier

* See Palmer on Shingle Beaches, Phil. Trans. 1834, p. 568.

or groin, after which they pour over in great numbers during heavy gales.*

The western entrance of the Channel, called the Solent, is crossed for more than two thirds of its width by the shingle-bank of Hurst Castle, which is about seventy yards broad and twelve feet high, presenting an inclined plane to the west. This singular bar consists of a bed of rounded chalk flints, resting on a submarine argillaceous base. The flints and a few other pebbles, intermixed, are exclusively derived from the waste of Hordwell, and other cliffs to the westward, where tertiary strata, capped with a covering of broken chalk flints, from five to fifty feet thick, are rapidly undermined. In the great storm of November, 1824, this bank of shingle was moved bodily forwards for forty yards towards the north-east; and certain piles, which served to mark the boundaries of two manors, were found after the storm on the opposite side of the bar. At the same time many acres of pasture land were covered by shingle, on the farm of Westover, near Lymington.

The cliffs between Hurst Shingle Bar and Christchurch are undermined continually. Within the memory of persons now living, it has been necessary thrice to remove the coast-road farther inland. The tradition, therefore, is probably true, that the church of Hordwell was once in the middle of that parish, although now very near the sea. The promontory of Christchurch Head gives way slowly. It is the only point between Lymington and Poole Harbour, in Dorsetshire, where any hard stony masses occur in the

* Groins are formed of piles and wooden planks, or of faggots staked down; and they are used either to break the force of the waves, or to retain the beach.

cliffs. Five layers of large ferruginous concretions, somewhat like the septaria of the London clay, have occasioned a resistance at this point, to which we may ascribe this headland. In the mean time, the waves have cut deeply into the soft sands and loam of Poole Bay ; and, after severe frosts, great landslips take place, which, by degrees, become enlarged into narrow ravines, or chines, as they are called, with vertical sides. One of these chines near Boscomb, has been deepened twenty feet within a few years. At the head of each there is a spring, the waters of which have been chiefly instrumental in producing these narrow excavations, which are sometimes from 100 to 150 feet deep.

Isle of Portland.—The peninsulas of Purbeck and Portland are continually wasting away. In the latter, the soft argillaceous substratum (Kimmeridge clay) hastens the dilapidation of the superincumbent mass of limestone.

In 1665 the cliffs adjoining the principal quarries in Portland gave way to the extent of one hundred yards, and fell into the sea ; and in December, 1734, a slide to the extent of 150 yards occurred on the east side of the isle, by which several skeletons, buried between slabs of stone, were discovered. But a much more memorable occurrence of this nature, in 1792, occasioned probably by the undermining of the cliffs, is thus described in Hutchins's History of Dorsetshire.—“ Early in the morning the road was observed to crack : this continued increasing, and before two o'clock the ground had sunk several feet, and was in one continued motion, but attended with no other noise than what was occasioned by the separation of the roots and brambles, and now and then a falling rock. At night it seemed to stop a little, but soon moved again ;

and before morning, the ground, from the top of the cliff to the water-side, had sunk in some places fifty feet perpendicular. The extent of ground that moved was about *a mile and a quarter* from north to south, and 600 yards from east to west.

Formation of the Chesil Bank.—Portland is connected with the mainland by the Chesil Bank, a ridge of shingle about seventeen miles in length, and, in most places, nearly a quarter of a mile in breadth. The pebbles forming this immense barrier are chiefly siliceous, all loosely thrown together, and rising to the height of from twenty to thirty feet above the ordinary high-water mark, at that part which is nearest the Isle of Portland. The fundamental rocks wheron the shingle rests are found at the depth of a few yards only below the level of the sea. The formation of that part of the bar which attaches Portland to the mainland, may have been due to an original shoal or reef, or to the set of the tides in the narrow channel, by which the course of the pebbles, which are always coming from the west, has been arrested. It is a singular fact that throughout the Chesil Bank the pebbles diminish gradually in size as we proceed westward, or as we approach the quarter from which they are supplied. Had the case been reversed, we should naturally have attributed the circumstance to the constant wearing down of the pebbles by friction, as they are rolled along a beach seventeen miles in length. We must now suppose that the velocity of the waves, due to the combined influence of the winds and tides, increases gradually from north-west to south-east, which is the direction of the beach. In that case the size of the masses coming from the westward and thrown ashore would be largest where the motion of the water was

most violent. Colonel Reid states that all calcareous stones rolled along from the west are soon ground into sand, and in this form they pass round Portland island.*

The storm of 1824 burst over the Chesil Bank with great fury, and the village of Chesilton, built upon its southern extremity, was overwhelmed, with many of the inhabitants. This same storm carried away part of the Breakwater at Plymouth, and huge masses of rock from two to five tons in weight, were lifted from the bottom of the weather side, and rolled fairly to the top of the pile. One block of limestone, weighing seven tons, was washed round the western extremity of the Breakwater, and carried 150 feet.† It was in the same month, and also during a spring-tide, that a great flood is mentioned on the coasts of England, in the year 1099. Florence of Worcester says, “On the third day of the nones of Nov. 1099, the sea came out upon the shore, and buried towns and men very many, and oxen and sheep innumerable.” We also read in the Saxon Chronicle, already cited, for the year 1099, “This year eke on St. Martin’s mass day, the 11th of Novembre, sprung up so much of the sea flood, and so myckle harm did, as no man minded that it ever afore did, and there was the ylk day a new moon.”

Dorsetshire—Devonshire. — At Lyme Regis, in Dorsetshire, the “Church Cliffs,” as they are called, consisting of lias about one hundred feet in height, have gradually fallen away, at the rate of one yard a year, since 1800: ‡

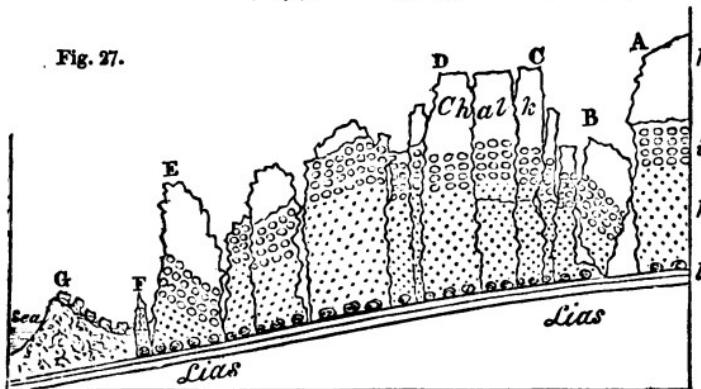
* See Palmer on Motion of Shingle Beaches, Phil. Trans. 1834, p. 568., and Col. Reid on the same, Professional Papers of Royal Engineers, 1838, vol. ii. p. 128.

† De la Beche, Geol. Man. p. 82.

‡ This ground was measured by Dr. Carpenter of Lyme, in

An extraordinary landslip occurred on the 24th of December, 1839, on the coast between Lyme Regis and Axmouth, which has been described by the Rev. W. D. Conybeare, to whose kindness I am indebted for an early communication on the subject. The tract of downs ranging there along the coast is capped by Chalk (*h*, fig. 27.), which rests on sandstone, alternating with chert (*i*), beneath which is more than 100 feet of loose sand (*k*), with concretions at the bottom, and belonging, like *i*, to the Green Sand formation; the whole of the above masses, *h*, *i*, *k*, reposing on retentive beds of clay (*l*), belonging to the Lias, which

Fig. 27.

*Landslip, near Axmouth, Dec. 1839. (Rev. W. D. Conybeare.)*

- A. Tract of Downs still remaining at their original level.
- B. New ravine.
- C, D. Sunk and fractured strip united to A, before the convulsion.
- D, E. Benton undercliff as before, but more fissured, and thrust forward about fifty feet towards the sea.
- F. Pyramidal crag, sunk from seventy to twenty feet in height.
- G. New reef upheaved from the sea.

shelves towards the sea. Numerous springs issuing from the loose sand (*k*) have gradually removed portions of it, and thus undermined the superstratum, so

1800, and again in 1829, as I am informed by Miss Mary Anning of Lyme, well known by her discoveries in fossil remains.

as to have caused subsidences at former times, and to have produced a line of undercliff between D and E. In 1839 an excessively wet season had saturated all the rocks with moisture, so as to increase the weight of the incumbent mass, from which the support had already been withdrawn by the action of springs. Thus the superstrata were precipitated into hollows prepared for them, and the adjacent masses of partially undermined rock, to which the movement was communicated, were made to slide down on a slippery basis of watery sand towards the sea. These causes gave rise to a convulsion, which began on the morning of the 24th of December, with a crashing noise; and, on the evening of the same day, fissures were seen opening in the ground, and the walls of tenements rending and sinking, until a deep chasm or ravine, B, was formed extending nearly three quarters of a mile in length, with a depth of from 100 to 150 feet, and a breadth exceeding 240 feet. At the bottom of this deep gulf lie fragments of the original surface thrown together in the wildest confusion. In consequence of lateral movements, the tract intervening between the new fissure and the sea, including the ancient undercliff, was fractured, and the whole line of sea-cliff carried bodily forwards for many yards. "A remarkable pyramidal crag, F, off Culverhole Point, which lately formed a distinguishing landmark, has sunk from a height of about seventy to twenty feet, and the main cliff, E, before more than fifty feet distant from this insulated crag, is now brought almost close to it. This motion of the sea-cliff has produced a futher effect, which may rank among the most striking phenomena of this catastrophe. The lateral pressure of the descending rocks has urged the neighbouring strata, extending be-

neath the shingle of the shore, by their state of unnatural condensation, to burst upwards in a line parallel to the coast,—thus an elevated ridge, G, more than a mile in length, and rising more than forty feet, covered by a confused assemblage of broken strata, and immense blocks of rock, invested with sea-weed and corallines, and scattered over with shells and star-fish, and other productions of the deep, forms an extended reef in front of the present range of cliffs.”*

Cornwall. — Near Penzance in Cornwall, there is a projecting tongue of land, called the “Green,” formed of granitic sand, from which more than thirty acres of pasture land have been gradually swept away in the course of the last two or three centuries.† It is also said that St. Michael’s Mount, now an insular rock, was formerly situated in a wood, several miles from the sea; and its old Cornish name (Caraclowse in Cowse) signifies, according to Carew, the Hoare Rock in the Wood.‡ Between the Mount and Newlyn there is seen under the sand black vegetable mould, full of hazel nuts, and the branches, leaves, roots, and trunks of forest trees, all of indigenous species. This stratum has been traced seaward as far as the ebb permits, and many proofs of a submerged vegetable accumulation, with stumps of trees in the position in which they grew, have been traced, says Mr. De la Beche, round the shores of Devon, Cornwall, and Western Somerset. The facts not only indicate a change in the relative level of the sea and land, since the species of animals and plants were the same as those now living in this

* Rev. W. D. Conybeare, letter dated Axminster, Dec. 31. 1899.

† Boase, Trans. Royal Geol. Soc. of Cornwall, vol. ii. p. 129.

‡ Ibid. p. 135.

district ; but, what is very remarkable, there seems evidence of the submergence having been effected, in part at least, since the country was inhabited by man.*

A submarine forest occurring at the mouth of the Parret in Somersetshire, on the south side of the Bristol Channel, was described by Mr. L. Horner, in 1815, and its position attributed to subsidence. A bed of peat is there seen below the level of the sea, and the trunks of large trees, such as the oak and yew, having their roots still diverging as they grew, and fixed in blue clay.†

Tradition of loss of land in Cornwall. — The oldest historians mention a celebrated tradition in Cornwall, of the submersion of the Lionnesse, a country which formerly stretched from the Land's End to the Scilly Islands. The tract, if it existed, must have been thirty miles in length, and perhaps ten in breadth. The land now remaining on either side is from two hundred to three hundred feet high ; the intervening sea about three hundred feet deep. Although there is no evidence for this romantic tale, it probably originated in some catastrophe occasioned by former inroads of the Atlantic, accompanying, perhaps, a subsidence of land on this coast.‡

West coast of England. — Having now brought together an ample body of proofs of the destructive operations of the waves, tides, and currents, on our eastern and southern shores, it will be unnecessary to enter into details of changes on the western coast, for they present merely a repetition of the same phenomena, and in general on an inferior scale. On the

* De la Beche's Report on the Geology of Devon, &c. chap. xiii.

† Geol. Trans., 1st series, vol. iii. p. 383.

‡ Boase, Trans. Royal Geol. Soc. of Cornwall, vol. ii. p. 130.

borders of the estuary of the Severn the flats of Somersetshire and Gloucestershire have received enormous accessions, while, on the other hand, the coast of Cheshire, between the rivers Mersey and Dee, has lost, since the year 1764, many hundred yards, and some affirm more than half a mile, by the advance of the sea upon the abrupt cliffs of red clay and marls. Within the period above mentioned several lighthouses have been successively abandoned.* There are traditions in Pembrokeshire† and Cardiganshire‡ of far greater losses of territory than that which the Lionnesse tale of Cornwall pretends to commemorate. They are all important, as demonstrating that the earliest inhabitants were familiar with the phenomenon of incursions of the sea.

Loss of land on the coast of France. — The French coast, particularly that of Brittany, where the tides rise to an extraordinary height, is the constant prey of the waves. In the ninth century many villages and woods are reported to have been carried away, the coast undergoing great change, whereby the hill of St. Michael was detached from the mainland. The parish of Bourgneuf, and several others in that neighbourhood, were overflowed in the year 1500. In 1735, during a great storm, the ruins of Palnel were seen uncovered in the sea. §

* Stevenson, Jameson's Ed. New Phil. Journ., No. 8. p. 386.

† Camden, who cites Gyraldus, also Ray, "On the Deluge," Phys. Theol. p. 228.

‡ Meyrick's Cardigan.

§ Von Hoff, Geschichte, &c. vol. i. p. 49.

CHAPTER VIII.

ACTION OF TIDES AND CURRENTS — *continued.*

Inroads of the sea upon the delta of the Rhine in Holland — Changes in the arms of the Rhine — Estuary of the Bies Bosch, formed in 1421 — Zuyder Zee, in the 13th century — Islands destroyed — Delta of the Ems converted into a bay — Estuary of the Dollart formed — Encroachment of the sea on the coast of Sleswick — On shores of North America — Tidal wave, called the Bore — Influence of tides and currents on the mean level of seas — Action of currents in inland lakes and seas — Baltic — Cimbrian deluge — Straits of Gibraltar — No under-current there — Whether salt is precipitated in the Mediterranean — Waste of shores of Mediterranean.

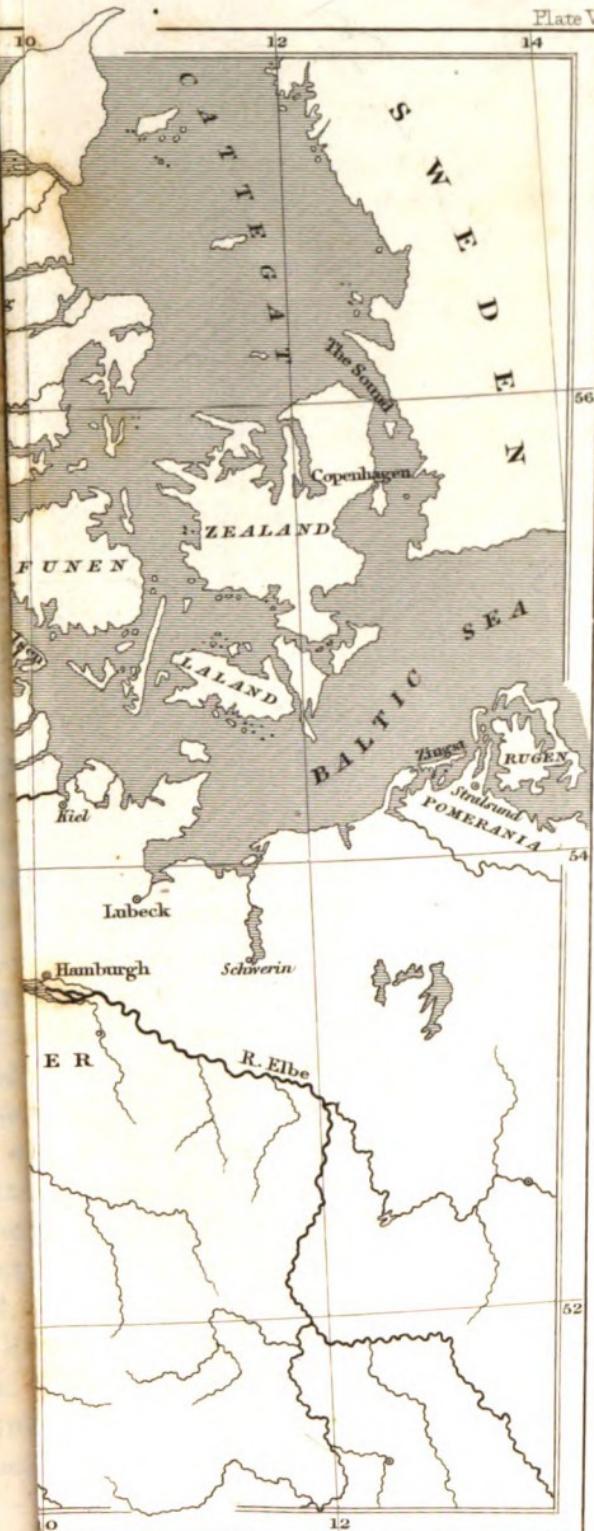
Inroads of the sea at the mouths of the Rhine. — THE line of British coast considered in the preceding chapter offered no example of the conflict of two great antagonist forces ; the influx, on the one hand, of a river draining a large continent, and on the other, the action of the waves, tides, and currents of the ocean. But when we pass over by the Straits of Dover to the Continent, and proceed north-eastwards, we find an admirable illustration of such a contest, where the ocean and the Rhine are opposed to each other, each disputing the ground now occupied by Holland ; the one striving to shape out an estuary, the other to form a delta. There was evidently a period when the river obtained the ascendancy, when the shape of the coast and set of the tides were probably very different ; but

for the last two thousand years, during which man has witnessed and actively participated in the struggle, the result has been in favour of the ocean ; the area of the whole territory having become more and more circumscribed ; natural and artificial barriers having given way, one after another ; and many hundred thousand human beings having perished in the waves.

Changes in the arms of the Rhine. — The Rhine, after flowing from the Grison Alps, copiously charged with sediment, first purifies itself in the Lake of Constance, where a large delta is formed ; then, swelled by the Aar and numerous other tributaries, it flows for more than six hundred miles towards the north : when, entering a low tract, it divides into two arms, north of Cleves, a little below the village of Pannerden — a point which must therefore be considered the head of its delta. (See map, Pl. 5.) In speaking of the delta I do not mean to assume that all that part of Holland which is comprised within the several arms of the Rhine can be called a delta in the strictest sense of the term ; because some portion of the country thus circumscribed, as, for example, a part of Gelderland and Utrecht, consists of strata which may have been deposited in the sea before the Rhine existed. These older tracts may either have been raised like the Ullah Bund in Cutch, during the period when the sediment of the Rhine was converting a part of the sea into land, or they may have constituted islands previously.

When the river divides north of Cleves, the left arm takes the name of the Waal ; and the right, retaining that of the Rhine, is connected, a little farther to the north, by an artificial canal with the river Yssel. Still lower down, the Rhine takes the name of the Leck, a name which was given to distinguish it from another

Plate V.



and before the 5th century, and afterwards

arm called the old Rhine, which was sanded up until after the year 1825, when a channel was cut for it, by which it now enters the sea at Catwyck. It is common, in all great deltas, that the principal channels of discharge should shift from time to time ; but in Holland so many magnificent canals have been constructed, and have so diverted, from time to time, the course of the waters, that the geographical changes in this delta are endless, and their history, since the Roman era, forms a complicated topic of antiquarian research. The present head of the delta is about forty geographical miles from the nearest part of the gulf called the Zuyder Zee, and more than twice that distance from the general coast-line. The present head of the delta of the Nile is about 80 or 90 geographical miles from the sea ; that of the Ganges, as before stated, 220 ; and that of the Mississippi about 180, reckoning from the point where the Atchafalaya branches off, to the extremity of the new tongue of land in the Gulf of Mexico. But the comparative distance between the heads of deltas and the sea affords scarcely any data for estimating the relative magnitude of the alluvial tracts formed by their respective rivers. For the ramifications depend on many varying and temporary circumstances, and the area over which they extend does not hold any constant proportion to the volume of water in the river.

The Rhine therefore has at present three mouths. About two thirds of its waters flow to the sea by the Waal, and the remainder is carried partly to the Zuyder Zee by the Yssel, and partly to the ocean by the Leck. As the whole coast to the south, as far as Ostend, and on the north, to the entrance of the Baltic, has, with few exceptions, from time immemorial,

yielded to the force of the waves, it is evident that the common delta of the Rhine, Meuse, and Scheldt, for these three rivers may all be considered as discharging their waters into the same part of the sea, would, if its advance had not been checked, have become extremely prominent; and even if it had remained stationary, would long ere this have projected far beyond the rounded outline of the coast, like that strip of land already described, at the mouth of the Mississippi. But we find, on the contrary, that the islands which skirt the coast have not only lessened in size, but in number also, while great bays have been formed in the interior by incursions of the sea.

I have said that the coast to the south as far as Ostend has given way. This statement may at first seem opposed to the fact that the tract between Antwerp and Nieuport, marked *a, a* on the annexed map, (plate 5.), although now dry land, and supporting a large population, has, within the historical period, been covered with the sea. This region, however, consisted, in the time of the Romans, of woods, marshes, and peat mosses, protected from the ocean by a chain of sandy dunes, which were afterwards broken through during storms, especially in the fifth century. The waters of the sea during these irruptions threw down upon the barren peat a horizontal bed of fertile clay, which is in some places three yards thick, full of recent shells and works of art. The inhabitants, by the aid of embankments and the sand dunes of the coast, have succeeded, although not without frequent disasters, in defending the soil thus raised by the marine deposit.*

* Belpaire, Mém. de l'Acad. Roy. de Bruxelles, tom. x.
1837. Dumont, Bulletin of the same Soc. tom. v. p. 643.

Inroads of the Sea in Holland. — If we pass to the northward of the territory just alluded to, and cross the Scheldt, we find that between the fourteenth and eighteenth centuries parts of the islands Walcheren and Beveland were swept away, and several populous districts of Kadzand, losses which far more than counterbalance the gain of land caused by the sanding up of some pre-existing creeks. In 1658 the island Orisant was annihilated. One of the most memorable inroads of the sea occurred in 1421, when the tide, pouring into the mouth of the united Meuse and Waal, burst through a dam in the district between Dort and Gertrudenberg, and overflowed seventy-two villages, forming a large sheet of water called the Bies Bosch. Thirty-five of the villages were irretrievably lost, and no vestige, even of their ruins, was afterwards seen. The rest were redeemed, and the site of the others, though still very generally represented on maps as an estuary, has in fact been gradually filled up by alluvial deposits, and had become in 1835, as I was informed by Professor Moll, an immense plain, yielding abundant crops of hay, though still uninhabited. To the north of the Meuse is a long line of shore covered with sand dunes, where great encroachments have taken place from time to time, in consequence chiefly of the prevalence of south-easterly winds, which blow down the sands towards the sea. The church of Scheveningen, not far from the Hague, was once in the middle of the village, and now stands on the shore; half the place having been overwhelmed by the waves in 1570. Catwyck, once far from the sea, is now upon the shore; two of its streets having been overflowed, and land torn away to the extent of 200 yards in 1719. It is only by aid of embankments, that Petten, and several

other places farther north, have been defended against the sea.

Formation of the Zuyder Zee and Straits of Staveren. — Still more important are the changes which have taken place on the coast opposite the right arm of the Rhine, or the Yssel, where the ocean has burst through a large isthmus, and entered the inland lake Flevo, which, in ancient times, was, according to Pomponius Mela, formed by the overflowing of the Rhine over certain lowlands. It appears that, in the time of Tacitus, there were several lakes on the present site of the Zuyder Zee, between Friesland and Holland. The successive inroads by which these, and a great part of the adjoining territory, were transformed into a great gulf, began about the commencement, and were completed towards the close of the thirteenth century. Alting gives the following relation of the occurrence, drawn from manuscript documents of contemporary inhabitants of the neighbouring provinces. In the year 1205, the island now called Wieringen, to the south of the Texel, was still a part of the mainland, but during several high floods, of which the dates are given, ending in December, 1251, it was separated from the continent. By subsequent incursions, the sea consumed great parts of the rich and populous isthmus, a low tract which stretched on the north of Lake Flevo, between Staveren in Friesland and Medemblick in Holland, till at length a breach was completed about the year 1282, and afterwards widened. Great destruction of land took place when the sea first broke in, and many towns were swept away; but there was afterwards a reaction to a certain extent, large tracts at first submerged, having been gradually redeemed. The new straits south of Staveren are more than half the

width of those of Dover, but are very shallow, the greatest depth not exceeding two or three fathoms. The new bay is of a somewhat circular form, and between *thirty* and *forty* miles in diameter. How much of this space may formerly have been occupied by Lake Flevo is unknown. (See Map, Plate 5.)

Destruction of Islands.—A series of islands stretching from the Texel to the mouths of the Weser and Elbe, are evidently the last relics of a tract once continuous. They have greatly diminished in size, and have lost about a third of their number since the time of Pliny; for that naturalist counted twenty-three islands between the Texel and Eider, whereas there are now only sixteen, including Heligoland and Neuwerk.* Heligoland, at the mouth of the Elbe, began in the year 800 to be much consumed by the waves. In the years 1300, 1500, and 1649, other parts were swept away, till at last a small portion only of the original island remained, consisting of a rock of red marl (of the keuper formation of the Germans), about 200 feet high. Since 1770, a current has cut a passage, navigable for large ships, through this remaining portion, and has formed two islands, Heligoland and Sandy Island.† On the other hand, some few islands have extended their bounds in one direction, or become connected with others, by the sanding-up of channels; but even these, like Juist, have generally given way as much on the north towards the sea as they have gained on the south, or land side.

The Dollart formed.—While the delta of the Rhine has suffered so materially from the movements of the ocean, it can hardly be supposed that minor rivers on

* Von Hoff, vol. i. p. 364,

† Id. p. 57.

the same coast should have been permitted to extend their deltas. It appears, that in the time of the Romans there was an alluvial plain of great fertility, where the Ems entered the sea by three arms. This low country stretched between Groningen and Friesland, and sent out a peninsula to the north-east towards Emden. A flood in 1277, first destroyed part of the peninsula. Other inundations followed at different periods throughout the fifteenth century. In 1507, a part only of Torum, a considerable town, remained standing ; and in spite of the erection of dams, the remainder of that place, together with market-towns, villages, and monasteries, to the number of fifty, were finally overwhelmed. The new gulf, which was called the Dollart, although small in comparison to the Zuyder Zee, occupied no less than six square miles at first ; but part of this space was, in the course of the two following centuries, again redeemed from the sea. The small bay of Leybucht, farther north, was formed in a similar manner in the thirteenth century ; and the bay of Harlbucht in the middle of the sixteenth. Both of these have since been partially reconverted into dry land. Another new estuary, called the Gulf of Jahde, near the mouth of the Weser, scarcely inferior in size to the Dollart, has been gradually hollowed out since the year 1016, between which era and 1651 a space of about four square miles has been added to the sea. The rivulet which now enters this inlet is very small ; but Arens conjectures, that an arm of the Weser had once an outlet in that direction.

Coast of Sleswick.— Farther north we find so many records of waste on the western coast of Sleswick, as to lead us to anticipate, that, at no distant period in the history of the physical geography of Europe,

Jutland may become an island, and the ocean may obtain a more direct entrance into the Baltic. Indeed, the temporary insulation of the northern extremity of Jutland has been effected no less than four times within the records of history, the ocean having as often made a breach through the bar of sand, which usually excludes it from the Lym Fiord. This long frith is 120 miles in length including its windings, and communicates at its eastern end with the Baltic. The last irruption of salt-water happened in 1824, and the fiord was still open in 1837, when some vessels of thirty tons burden passed through.

The Marsh islands between the rivers Elbe and Eyder are mere banks, like the lands formed of the "warp" in the Humber, protected by dikes. Some of them, after having been inhabited with security for more than ten centuries, have been suddenly overwhelmed. In this manner, in 1216, no less than ten thousand of the inhabitants of Eyderstede and Ditzmarsch perished; and on the 11th of October, 1634, the islands and the whole coast, as far as Jutland, suffered by a dreadful deluge.

Destruction of Northstrand by the Sea. — Northstrand, up to the year 1240, was, with the islands Sylt and Föhr, so nearly connected with the mainland as to appear a peninsula, and was called North Friesland, a highly cultivated and populous district. It measured from nine to eleven geographical miles from north to south, and six to eight from east to west. In the above-mentioned year it was torn asunder from the continent, and in part overwhelmed. The Isle of Northstrand, thus formed, was, towards the end of the sixteenth century, only four geographical miles in circumference, and was still celebrated for its cultivation

and numerous population. After many losses, it still contained nine thousand inhabitants. At last, in the year 1634, on the evening of the 11th of October, a flood passed over the whole island, whereby 1300 houses, with many churches, were lost; fifty thousand head of cattle perished, and above six thousand men. Three small islets, one of them still called Northstrand, alone remained, which are now continually wasting.

The redundancy of river water in the Baltic, especially during the melting of ice and snow in spring, causes in general an outward current through the channel called the Cattegat. But after a continuance of north-westerly gales, especially during the height of the spring tides, the Atlantic rises; and, pouring a flood of water into the Baltic, commits dreadful devastations on the isles of the Danish Archipelago. This current even acts, though with diminished force, as far eastward as the vicinity of Dantzig.* Accounts written during the last ten centuries attest the wearing down of promontories on the Danish coast, the deepening of gulfs, the severing of peninsulas from the mainland, and the waste of islands, while in several cases marsh land, defended for centuries by dikes, has at last been overflowed, and thousands of the inhabitants whelmed in the waves.

Thus the island Barsoe, on the coast of Sleswick, has lost, year after year, an acre at a time. (See map, plate 5.) The island Alsen suffers in like manner. The peninsula Zingst was converted into an island in 1625. There is a tradition that the isle of Rugen was originally torn by a storm from the mainland of Pomerania: and it is known, in later times, to have lost

* See examples in Von Hoff, vol. i. p. 73., who cites Pisansky.

ground, as in the year 1625, when a tract of land was carried away. Some of these islands consist of ancient alluvial accumulations, containing blocks of granite, which are also spread over the neighbouring mainland.

Cimbrian Deluge.—As we have already seen that during the flood before mentioned 6000 men and 50,000 head of cattle perished on Northstrand on the western coast of Jutland, we are well prepared to find that this peninsula, the Cimbrica Chersonesus of the ancients, has from a remote period been the theatre of like catastrophes. Accordingly, Strabo records a story, although he treats it as an incredible fiction, that during a high tide, the ocean rose upon this coast so rapidly, that men on horseback were scarce able to escape.* Florus, alluding to the same tradition, says, “Cimbri, Theutoni, atque Tigurini, ab extremis Galliæ profugi, cùm terras eorum inundasset Oceanus, novas sedes toto orbe quærebant.”† This event, commonly called the “Cimbrian Deluge,” is supposed to have happened about three centuries before the Christian era, but it is not improbable that the principal catastrophe was preceded and followed by many devastations like those experienced in modern times on the islands and shores of Jutland; and such calamities may well be conceived to have forced on the migration of some maritime tribes.

Inroads of the sea on the eastern shores of North America.—After so many authentic details respecting the destruction of the coast in parts of Europe best known, it will be unnecessary to multiply examples of analogous changes in more distant regions of the world.

* Book vii. Cimbri.

† Lib. iii. cap. 3.

It must not, however, be imagined that our own seas form any exception to the general rule. Thus, for example, if we pass over to the eastern coast of North America, where the tides rise to a great elevation, we find many facts attesting the incessant demolition of land. At Cape May, for example, on the north side of Delaware Bay, in the United States, the encroachment of the sea was shown by observations made consecutively for sixteen years, from 1804 to 1820, to average about nine feet a year*; and at Sullivan's Island, which lies on the north side of the entrance of the harbour of Charlestown, in South Carolina, the sea carried away a quarter of a mile of land in three years, ending in 1786. †

Tidal wave called "the Bore." — Before concluding my remarks on the action of the tides, I must not omit to mention the wave called "the Bore," which is sometimes produced in a river where a large body of water is made to rise suddenly, in consequence of the contraction of the channel. This wave terminates abruptly on the inland side; because the quantity of water contained in it is so great, and its motion so rapid, that time is not allowed for the surface of the river to be immediately raised by means of transmitted pressure. A tide wave thus rendered abrupt has a close analogy, observes Mr. Whewell, to the waves which curl over and break on a shelving shore.‡

The Bore which enters the Severn, where the phenomenon is of almost daily occurrence, is sometimes nine feet high, and at spring tides rushes up the estuary with extraordinary rapidity. The same phe-

* New Monthly Mag. vol. vi. p. 69.

† Von Hoff, vol. i. p. 96.

‡ Phil. Trans. 1833, p. 204.

nomenon is frequently witnessed in the principal branches of the Ganges, and in the Megna. "In the Hoogly, or Calcutta river," says Rennell, "the Bore commences at Hoogly Point, the place where the river first contracts itself, and is perceptible above Hoogly Town; and so quick is its motion, that it hardly employs four hours in travelling from one to the other, though the distance is nearly seventy miles. At Calcutta it sometimes occasions an instantaneous rise of five feet; and both here, and in every other part of its track, the boats, on its approach, immediately quit the shore, and make for safety to the middle of the river. In the channels, between the islands in the mouth of the Megna, the height of the Bore is said to exceed twelve feet; and is so terrific in its appearance, and dangerous in its consequences, that no boat will venture to pass at spring tide."* These waves may sometimes cause inundations, undermine cliffs, and still more frequently sweep away trees and land animals from low shores, so that they may be carried down, and ultimately imbedded in fluviatile or submarine deposits.

CURRENTS IN INLAND LAKES AND SEAS.

In such large bodies of water as the North American lakes, the continuance of a strong wind in one direction often causes the elevation of the water, and its accumulation on the leeward side; and while the equilibrium is restoring itself, powerful currents are occasioned. In October 1833, a strong current in Lake Erie, caused partly by the set of the waters

* Rennell, Phil. Trans. 1781.

towards the outlet of the lake, and partly by the prevailing wind, burst a passage through the extensive peninsula called Long Point, and soon excavated a channel more than nine feet deep and nine hundred feet wide. Its width and depth have since increased, and a new and costly pier has been erected; for it is hoped that this event will permanently improve the navigation of Lake Erie for steam-boats.* On the opposite, or southern coast of this lake, in front of the town of Cleveland, the degradation of the cliffs had been so rapid for several years preceding a survey made in 1837, as to threaten many towns with demolition.† In the Black Sea, also, although free from tides, we learn from Pallas that there is a sufficiently strong current to undermine the cliffs in many parts, and particularly in the Crimea.

Straits of Gibraltar. — That the level of the Mediterranean is from twenty to thirty feet lower than that of the Red Sea, at Suez, has been already stated.‡

It is well known that a powerful current sets constantly from the Atlantic into the Mediterranean, and its influence extends along the whole southern borders of that sea, and even to the shores of Asia Minor. Captain Smyth found, during his survey, that the central current ran constantly at the rate of from three to six miles an hour eastward into the Mediterranean, the body of water being three miles and a half wide. But there are also two lateral currents — one on the European, and one on the African side; each of them about two miles and a half broad,

* MS. of Capt. Bayfield, R. N.

† Silliman's Journ., vol. xxxiv. p. 349.

‡ See p. 31.

and flowing at about the same rate as the central stream. These lateral currents ebb and flow with the tide, setting alternately into the Mediterranean and into the Atlantic. The excess of water constantly flowing in is very great, and there is only one cause to which this can be attributed, the loss of water in the Mediterranean by evaporation. That the level of this sea should be considerably depressed by this cause is quite conceivable, since we know that the winds blowing from the shores of Africa are hot and dry; and hygrometrical experiments recently made in Malta and other places, show that the mean quantity of moisture in the air investing the Mediterranean, is equal only to one half of that in the atmosphere of England. The temperature also of the great inland sea is upon an average higher, by $3\frac{1}{2}$ ^o of Fahrenheit, than the eastern part of the Atlantic ocean in the same latitude, which must greatly promote its evaporation. The Black Sea being situated in a higher latitude, and being the receptacle of rivers flowing from the north, is much colder, and its expenditure far less; accordingly, it does not draw any supply from the Mediterranean, but, on the contrary, contributes to it by a current flowing outwards, for the most part of the year, through the Dardanelles. The discharge, however, at the Bosphorus is so small, when compared to the volume of water carried in by rivers, as to imply a great amount of evaporation even in the Black Sea.

Whether salt be precipitated in the Mediterranean. — It is, however, objected, that evaporation carries away only fresh water, and that the current from the Atlantic is continually bringing in salt water: why, then, do not the component parts of the waters of the Mediterranean vary? or how can they remain so nearly

the same as those of the ocean? Some have imagined that the excess of salt might be carried away by an under-current running in a contrary direction to the superior; and this hypothesis appeared to receive confirmation from a late discovery that the water taken up about fifty miles within the Straits, from a depth of 670 fathoms, contained a quantity of salt *four times greater* than the water of the surface. Dr. Wollaston *, who analysed this water obtained by Captain Smyth, truly inferred that an under-current of such denser water flowing outward, if of equal breadth and depth with the current near the surface, would carry out as much salt below as is brought in above, although it moved with less than one fourth part of the velocity, and would thus prevent a perpetual increase of saltiness in the Mediterranean beyond that existing in the Atlantic. It was also remarked by others, that the result would be the same if, the swiftness being equal, the inferior current had only one fourth of the volume of the superior. At the same time there appeared reason to conclude that this great specific gravity was only acquired by water at immense depths; for two specimens of the water, taken within the Mediterranean, at the distance of some hundred miles from the Straits, and at depths of 400, and even 450 fathoms, were found by Dr. Wollaston not to exceed in density that of many ordinary samples of sea-water. Such being the case, we can now prove that the vast amount of salt brought into the Mediterranean, *does not pass out again* by the Straits; for it appears by Captain Smyth's soundings, which Dr. Wollaston had not seen, that between the capes of Trafalgar and Spartel, which

* Phil. Trans. 1829, part i. p. 29.

are twenty-two miles apart, and where the Straits are shallowest, the deepest part, which is on the side of Cape Spartel, is only 220 fathoms. It is therefore evident, that if water sinks in certain parts of the Mediterranean, in consequence of the increase of its specific gravity, to greater depths than 220 fathoms, it can never flow out again into the Atlantic, since it must be stopped by the submarine barrier which crosses the shallowest part of the Straits of Gibraltar.

The idea of the existence of a counter-current, at a certain depth, first originated in the following circumstance ;—M. De l'Aigle, commander of a privateer called the *Phœnix* of Marseilles, gave chase to a Dutch merchant-ship, near Ceuta Point, and coming up with her in the middle of the gut, between Tariffa and Tangier, gave her one broadside, which directly sunk her. A few days after, the sunken ship, with her cargo of brandy and oil, was cast ashore near Tangier, which is at least four leagues to the westward of the place where she went down, and to which she must have floated in a direction contrary to the course of the *central* current.* This fact, however, affords no evidence of an under-current, because the ship, when it approached the coast, would necessarily be within the influence of a lateral current, which, running westward twice every twenty-four hours, might have brought back the vessel to Tangier.

What, then, becomes of the excess of salt? — for this is an inquiry of the highest geological interest. The Rhone, the Po, the Nile, and many hundred minor streams and springs, pour annually into the Mediterranean large quantities of carbonate of lime, together

* Phil. Trans. 1724.

with iron, magnesia, silica, alumina, sulphur, and other mineral ingredients, in a state of chemical solution. To explain why the influx of this matter does not alter the composition of this sea has never been regarded as a difficulty ; for it is known that calcareous rocks are forming in the delta of the Rhone, in the Adriatic, on the coast of Asia Minor, and in other localities. Precipitation is acknowledged to be the means whereby the surplus mineral matter is disposed of, after the consumption of a certain portion in the secretions of testacea, zoophytes, and other marine animals. But before muriate of soda can, in like manner, be precipitated, the whole Mediterranean ought, according to the received principles of chemistry, to become as much saturated with salt as Lake Aral, the Dead Sea, or the brine-springs of Cheshire.

It is undoubtedly true, in regard to small bodies of water, that every particle must be fully saturated with muriate of soda, before a single crystal of salt can be formed ; such is probably the case in all natural salterns : such, for example, as those described by travellers as occurring on the western borders of the Black Sea, where extensive marshes are said to be covered by thin films of salt after a rapid evaporation of sea-water. The salt *étangs* of the Rhone, where salt has sometimes been precipitated in considerable abundance, have been already mentioned. But if the era of the almost complete separation of the Mediterranean from the ocean be of no higher antiquity than the deposition of the newest tertiary strata found at the northern base of the Pyrenees, it is conceivable that this inland sea, especially if its depth be enormous, may have grown more and more saline ever since its actual basin was formed, and yet there may not have

been time, even at great depths, for the acquisition of saltiness approaching that of the Dead Sea.

In regard to the depth of the Mediterranean, it appears that the narrowest part of the Straits of Gibraltar, where they are about nine miles broad, between the Isle of Tariffa and Alcanzar Point, the depth of water varies from 160 to 500 fathoms : but between Gibraltar and Ceuta, Captain Smyth sounded to the enormous depth of 950 fathoms ; where he found a gravelly bottom, with fragments of broken shells. Saussure sounded to the depth of two thousand feet, within a few yards of the shore, at Nice ; and M. Bérard has lately fathomed to the depth of more than six thousand feet in several places without reaching the bottom.*

The central abysses, therefore, of this sea are, in all likelihood, at least as deep as the Alps are high ; and, as at the depth of seven hundred fathoms only, water has been found to contain a proportion of salt four times greater than at the surface, we may presume that the excess of salt may be much greater at the depth of two or three miles. After evaporation, the surface water becomes impregnated with a slight excess of salt, and its specific gravity being thus increased, it instantly falls to the bottom, while lighter water rises to the top, or flows in laterally, being always supplied by rivers and the current from the Atlantic. The heavier fluid, when it arrives at the bottom, cannot stop if it can gain access to any lower part of the bed of the sea, not previously occupied by water of the same density.

How far this accumulation of brine can extend before the inferior strata of water will part with any

* Bull. de la Soc. Géol. de France. — Résumé, p. 72. 1832.

of their salt, and what difference in such a chemical process the immense pressure of the incumbent ocean might occasion, are questions which cannot be answered in the present state of science.

The Straits of Gibraltar are said to become gradually wider by the wearing down of the cliffs on each side at many points ; and the current sets along the coast of Africa, so as to cause considerable inroads in various parts, particularly near Carthage. Near the Canopic mouth of the Nile, at Aboukir, the coast was greatly devastated in the year 1784, when a small island was nearly consumed. By a series of similar operations, the old site of the cities of Nicopolis, Taposiris, Parva, and Canopus, have become a sand-bank.*

* Clarke's Travels in Europe, Asia, and Africa, vol. iii. pp. 340. and 363. 4th edition.

CHAPTER IX.

REPRODUCTIVE EFFECTS OF TIDES AND CURRENTS.

Silting up of estuaries does not compensate the loss of land on the borders of the ocean — Bed of the German Ocean — Composition and extent of its sand-banks — Strata deposited by currents on the southern and eastern shores of the Mediterranean — Transportation by currents of the sediment of the Amazon, Orinoco, and Mississippi — Stratification.

FROM the facts enumerated in the last chapter, it appears that, on the borders of the ocean, currents and tides co-operating with the waves of the sea are most powerful instruments in the destruction and transportation of rocks; and as numerous tributaries discharge their alluvial burden into the channel of one great river, so we find that many rivers deliver their earthy contents to one marine current, to be borne by it to a distance, and deposited in some deep receptacle of the ocean. The current not only receives this tribute of sedimentary matter from streams draining the land, but acts also itself on the coast, as does a river on the cliffs which bound a valley. The course of currents on the British shores is ascertained to be as tortuous as that of ordinary rivers. Sometimes they run between sand-banks, which consist of matter thrown down at certain points where the velocity of the stream had been retarded; but it very frequently happens, that as in a river one bank is made of low alluvial gravel,

while the other is composed of some hard and lofty rock constantly undermined, so the current, in its bends, strikes here and there upon a coast, which then forms one bank, while a shoal under water forms the other. If the coast be composed of solid materials, it yields slowly; so also if it be of great height, for in that case a large quantity of matter must be removed before the sea can penetrate to any distance.

In inland seas, where the tides are insensible, or on those parts of the borders of the ocean where they are feeble, it is scarcely possible to prevent a harbour at a river's mouth from silting up; for a bar of sand or mud is formed at points where the velocity of the turbid river is checked by the sea, or where the river and a marine current neutralize each other's force. For the current, as we have seen, may, like the river, hold in suspension a large quantity of sediment, or, co-operating with the waves, may cause the progressive motion of a shingle beach in one direction. I have already alluded to the erection of piers and groins at certain places on our southern coast, to arrest the course of the shingle and sand (see p. 73.). The immediate effect of these temporary obstacles is to cause a great accumulation of pebbles on one side of the barrier, after which the beach still moves on round the end of the pier at a greater distance from the land. This system, however, is often attended with a serious evil, for during storms the waves throw suddenly into the harbour the vast heap of pebbles which have collected for years behind the groin or pier, as happened in the late gale (Jan. 1839) at Dover.

Estuaries, how formed. — The formation and keeping open of large estuaries are due to the *combined influence* of tidal currents and rivers; for when the tide rises, a

large body of water suddenly enters the mouth of the river, where, becoming confined within narrower bounds, while its momentum is not destroyed, it is urged on, and, having to pass through a contracted channel, rises and runs with increased velocity, just as a stream, when it reaches the arch of a bridge scarcely large enough to give passage to its waters, rushes with a steep fall through the arch. During the ascent of the tide, a body of fresh water, flowing down in an opposite direction from the higher country, is arrested in its course for several hours; and thus a large lake of brackish water is accumulated, which, when the sea ebbs, is let loose, as on the removal of an artificial sluice or dam. By the force of this retiring water, the alluvial sediment both of the river and of the sea is swept away, and transported to such a distance from the mouth of the estuary, that a small part only can return with the next tide.

It sometimes happens, that during a violent storm a large bar of sand is suddenly made to shift its position, so as to prevent the free influx of the tides, or efflux of river water. Thus about the year 1500 the sands at Bayonne were suddenly thrown across the mouth of the Adour. That river, flowing back upon itself, soon forced a passage to the northward, along the sandy plain of Capbreton, till at last it reached the sea at Boucau, at the distance of *seven leagues* from the point where it had formerly entered. It was not till the year 1579 that the celebrated architect Louis de Foix, undertook, at the desire of Henry III., to re-open the ancient channel, which he at last effected with great difficulty.*

* Nouvelle Chronique de la Ville de Bayonne, pp. 113. 139.
1827.

Tides in Estuaries.—In the estuary of the Thames at London, and in the Gironde, the tide rises only for five hours and ebbs seven, and in all estuaries the water requires a longer time to run down than up; so that the preponderating force is always in the direction which tends to keep open a deep and broad passage. But for reasons already explained, there is naturally a tendency in all estuaries to silt up partially, since eddies, and backwaters, and points where opposing streams meet, are very numerous, and constantly change their position.

Silting up of estuaries does not compensate for loss of coasts.—Many writers have declared that the gain on our eastern coast, since the earliest periods of history, has more than counterbalanced the loss; but they have been at no pains to calculate the amount of loss, and have often forgotten that, while the new acquisitions are manifest, there are rarely any natural monuments to attest the former existence of the land that has been carried away. They have also taken into their account those tracts artificially recovered, which are often of great agricultural importance, and may remain secure, perhaps, for thousands of years, but which are only a few feet above the mean level of the sea, and are therefore exposed to be overflowed again by a small proportion of the force required to remove cliffs of considerable height on our shores. If it were true that the area of land annually abandoned by the sea in estuaries were equal to that invaded by it, there would still be no compensation *in kind*.

It will seem, at first sight, somewhat paradoxical, but it is nevertheless true, that the greater number of estuaries, although peculiarly exposed to the invasion of the sea, are usually contracting in size, even where

the whole line of coast is giving way. But the fact is, that the inroads made by the ocean upon estuaries, although extremely great, are completed during periods of comparatively short duration; and in the intervals between these irruptions, the mouths of rivers, like other parts of the coast, usually enjoy a more or less perfect respite. All the estuaries, taken together, constitute but a small part of a great line of coast; it is, therefore, most probable, that if our observations extend to a few centuries only, we shall not see any, and very rarely all, of this small part exposed to the fury of the ocean. The coast of Holland, and Friesland, if studied for several consecutive centuries since the Roman era, would generally have led to the conclusion that the land was encroaching fast upon the sea, and that the aggrandisement within the estuaries far more than compensated the losses on the open coast. But when our retrospect embraces the whole period, an opposite inference is drawn: and we find that the Zuyder Zee, the Bies Bosch, Dollart, and Jahde, are modern gulfs and bays, and that these points have been the principal theatres of the retreat, instead of the advance, of the land. If we possessed records of the changes on our coast for several thousand years, they would probably present us with similar results; and although we have hitherto seen our estuaries, for the most part, become partially converted into dry land, and bold cliffs intervening between the mouths of rivers consumed by the sea, this has merely arisen from the accidental set of the currents and tides during a brief period.

The current which flows round from the north-west, and bears against the eastern coast of England, transports, as we have seen, materials of various kinds.

Aided by the winds and waves, it undermines and sweeps away the granite, gneiss, trap rocks, and sand-stone of Shetland, and removes the gravel and loam of the cliffs of Holderness, Norfolk, and Suffolk, which are between fifty and two hundred feet in height, and which waste at the rate of from one to six yards annually. It also bears away, in co-operation with the Thames and the tides, the strata of London clay on the coast of Essex and Sheppey. The sea at the same time consumes the chalk with its flints for many miles continuously on the shores of Kent and Sussex — commits annual ravages on the fresh-water beds, capped by a thick covering of chalk-flint gravel, in Hampshire, and continually saps the foundations of the Portland limestone. It receives, besides, during the rainy months, large supplies of pebbles, sand, and mud, which numerous streams from the Grampians, Cheviots, and other chains, send down to the sea. To what regions, then, is all this matter consigned? It is not retained in mechanical suspension by the waters of the ocean, nor does it mix with them in a state of chemical solution, — it is deposited *somewhere*, yet certainly not in the immediate neighbourhood of our shores ; for, in that case, there would soon be a cessation of the encroachment of the sea, and large tracts of low land, like Romney Marsh, would almost everywhere encircle our island.

As there is now a depth of water, exceeding thirty feet, in some spots where towns like Dunwich flourished but a few centuries ago, it is clear that the current not only carries far away the materials of the wasted cliffs, but removes also the ruins of many of the regular strata at the bottom of the sea.

So great is the quantity of matter held in suspension

by the tidal current on our shores, that the waters are in some places artificially introduced into certain lands below the level of the sea; and by repeating this operation, which is called "warping," for two or three years, considerable tracts have been raised, in the estuary of the Humber, to the height of about six feet. If a current, charged with such materials, meets with deep depressions in the bed of the ocean, it must often fill them up; just as a river, when it meets with a lake in its course, fills it gradually with sediment.

The only records which we at present possess of the gradual shallowing of seas are confined, as might be expected, to estuaries, havens, and certain channels of no great depth; and to some inland seas, as the Baltic, Adriatic, and Arabian Gulf. It is only of late years, that accurate surveys and soundings have afforded data of comparison in very deep seas, of which future geologists will avail themselves.

An extraordinary gain of land is described to have taken place at the head of the Red Sea, the Isthmus of Suez having doubled in breadth since the age of Herodotus. In his time, and down to that of Arrian, Heroopolis was on the coast; now it is as far distant from the Red Sea as from the Mediterranean.* Suez in 1541 received into its harbour the fleet of Solyman II.; but it is now changed into a sand-bank. The country called Tehama on the Arabian side of the gulf has increased from three to six miles since the Christian era. Inland from the present ports are the ruins of more ancient towns, which were once on the sea-shore, and bore the same names. It is said that

* Danville, *Mém. sur l'Egypte*, p. 108. — Von Hoff, vol. i. p. 390.

the blown sand from the deserts supplies some part of the materials of this new land, and that the rest is composed of shells and corals, of which the growth is very rapid.

Filling up of the German Ocean. — The German Ocean is deepest on the Norwegian side, where the soundings give 190 fathoms; but the mean depth of the whole basin may be stated at no more than thirty-one fathoms.* The bed of this sea is traversed by several enormous banks, one of which, occupying a central position, trends from the Frith of Forth, in a north-easterly direction, to a distance of 110 miles; others run from Denmark and Jutland upwards of 105 miles to the north-west; while the greatest of all, the Dogger Bank, extends for upwards of 354 miles from north to south. The whole superficies of these enormous shoals is equal to about one fifth of the whole area of the German Ocean, or to about one third of the whole extent of England and Scotland.† The average height of the banks measures, according to Mr. Stevenson, about seventy-eight feet; the upper portion of them consisting of fine and coarse siliceous sand, mixed with comminuted corals and shells.‡

It has been supposed by some writers, that these vast submarine hills are made up bodily of drift sand, and other loose materials, principally supplied from the waste of the English, Dutch, and other coasts. But the late survey of the North Sea, conducted by Captain Hewett, affords ground for suspecting that this opinion is very erroneous. If such immense mounds of sand and mud had been accumulated under

* Stevenson on the Bed of the German Ocean, or North Sea.—Ed. Phil. Journ. No. V. p. 44. 1820.

† Ibid. p. 47.

‡ Ibid.

the influence of currents, the same causes ought nearly to have reduced to a level the entire bottom of the German Ocean; instead of which some long narrow ravines are found to intersect the banks. One of these varies from seventeen to forty-four fathoms in depth, and has very precipitous sides: in one part, called the "Inner Silver Pits," it is fifty-five fathoms deep. The shallowest parts of the Dogger Bank were found to be forty-two feet under water, except in one place, where the wreck of a ship had caused a shoal; so that we may suppose the currents, which vary in their velocity from a mile to two miles and a half per hour, to have power to prevent the accumulation of drift matter in places of less depth. It seems, then, that the great banks above alluded to, and the ravines which intersect them, cannot be due to the tides and currents now existing in this sea. They may, however, have been caused in great part by the movements of the ocean at some former period, when the bed of this sea, and the surface of the land adjoining, assumed its actual configuration.

Strata deposited by currents.—It appears extraordinary, that in some tracts of the sea, adjoining the coast of England, where we know that currents are not only sweeping along rocky masses, thrown down, from time to time, from the high cliffs, but also occasionally scooping out channels in the regular strata, there should exist fragile shells and tender zoophytes in abundance, which live uninjured by these violent movements. The ocean, however, is in this respect a counterpart of the land; and as, on the continents, rivers may undermine their banks, uproot trees, and roll along sand and gravel, while their waters are inhabited by testacea and fish, and their alluvial plains are

adorned with rich vegetation and forests, so the sea may be traversed by rapid currents, and its bed may here and there suffer great local derangement, without any interruption of the general order and tranquillity.

One important character in the formations produced by currents, is, the immense extent over which they may be the means of diffusing homogeneous mixtures, for these are often co-extensive with a great line of coast, and, by comparison with their deposits, the deltas of rivers must shrink into insignificance. In the Mediterranean, the same current which is rapidly destroying many parts of the African coast, between the Straits of Gibraltar and the Nile, preys also upon the delta of the Nile, and drifts the sediment of that great river to the eastward. To this source may be attributed the rapid accretions of land on parts of the Syrian shores where rivers do not enter.

It is the opinion of M. Girard, one of the scientific men who accompanied Napoleon's expedition to Egypt, and who were employed on the survey of the ancient canal of Amron, communicating between the Nile and the Red Sea, that the Isthmus of Suez itself is merely a bar formed by the deposition of this current and of the Nile, and that the two seas were formerly united.* It is certain, as before stated, that the isthmus is daily gaining in width by the accession of fresh deposits on the shores of the Mediterranean.†

Distribution of the sediment of the Amazon by currents. — Among the greatest deposits now in progress, and of which the distribution is chiefly determined by currents, we may class those between the mouths of

* Description de l'Egypte, Mémoires, tom. i. p. 88.

† Quarterly Review, No. lxxxvi. p. 445.

the Amazon and the southern coast of North America. It has been before stated that a great current flows along the coast of Africa, from the south, which, when it reaches the head of the Gulf of Guinea, and is opposed by the waters brought to the same spot by the Guinea current, streams off in a westerly direction, and pursues its rapid course quite across the Atlantic to the continent of South America. Here one portion proceeds along the northern coast of Brazil to the Caribbean Sea and the Gulf of Mexico. Captain Sabine found that this current was running with the astonishing rapidity of four miles an hour where it crosses the stream of the Amazon, which river preserves part of its original impulse, and has its waters not wholly mingled with those of the ocean at the distance of three hundred miles from its mouth.* The sediment of the Amazon is thus constantly carried to the north-west as far as to the mouths of the Orinoco, and an immense tract of swamp is formed along the coast of Guiana, with a long range of muddy shoals bordering the marshes, and becoming converted into land.† The sediment of the Orinoco is partly detained, and settles near its mouth, causing the shores of Trinidad to extend rapidly, and is partly swept away into the Caribbean Sea by the Guinea current. According to Humboldt, much sediment is carried again out of the Caribbean Sea into the Gulf of Mexico. The rivers, also, which descend from the high platform of Mexico, between the mouths of the Norte and Tampico, when they arrive, swollen by tropical

* Experiments to determine the Figure of the Earth, &c.
p. 445.

† Lochead's Observations on the Nat. Hist. of Guiana. Edin.
Trans. vol. iv.

rains, at the edge of that platform, bear down an enormous quantity of rock and mud to the sea; but the current, setting across their mouths, prevents the growth of deltas, and preserves an almost uniform curve in that line of coast.* It must, therefore, exert a great transporting power, and it cannot fail to sweep away part of the matter which is discharged from the mouths of the Norte and the Mississippi.

Area over which strata may be formed by currents. — In regard to the distribution of sediment by currents, it may be observed, that the rate of subsidence of the finer mud carried down by every great river into the ocean, or of that caused by the rolling of the waves upon a shore, must be extremely slow; for the more minute the separate particles of mud, the slower will they sink to the bottom, and the sooner will they acquire what is called their terminal velocity. It is well known that a solid body, descending through a resisting medium, falls by the force of gravity, which is constant, but its motion is resisted by the medium more and more as its velocity increases, until the resistance becomes sufficient to counteract the further increase of velocity. For example, a leaden ball, one inch diameter, falling through air of density as at the earth's surface, will never acquire greater velocity than 260 feet per second, and, in water, its greatest velocity will be 8 feet 6 inches per second. If the diameter of the ball were $\frac{1}{10}$ of an inch, the terminal velocities in air would be 26 feet, and in water .86 of a foot per second.

Now, every chemist is familiar with the fact, that minute particles descend with extreme slowness

* This coast has been examined by Captain Vetch. — See also Bauza's chart of the Gulf of Mexico.

through water, the extent of their surface being very great in proportion to their weight, and the resistance of the fluid depending on the amount of surface. A precipitate of sulphate of baryta, for example, will sometimes require more than five or six hours to subside one inch *; while oxalate and phosphate of lime require nearly an hour to subside about an inch and a half and two inches respectively †, so exceedingly small are the particles of which these substances consist.

When we recollect that the depth of the ocean is supposed frequently to exceed three miles, and that currents run through different parts of that ocean at the rate of four miles an hour, and when at the same time we consider that some fine mud carried away from the mouths of rivers and from sea-beaches, where there is a heavy surf, as well as the impalpable powder showered down by volcanos, may subside at the rate of only an inch per hour, we shall be prepared to find examples of the transportation of sediment over areas of indefinite extent.

It is not uncommon for the emery powder used in polishing glass, to take more than an hour to sink one foot. Suppose mud, composed of particles twice as coarse, to fall at the rate of two feet per hour, and these to be discharged into that part of the Gulf Stream which preserves a mean velocity of three miles an hour for a distance of two thousand miles; in twenty-eight days these particles will be carried 2016 miles, and will have fallen only to a depth of 224 fathoms.

In this example, however, it is assumed that the

* On the authority of Mr. Faraday.

† On the authority of Mr. R. Phillips.

current retains its superficial velocity at the depth of 224 fathoms, for which we have as yet no data. Experiments should be made to ascertain the rate of currents at considerable distances from the surface, and the time taken by the finest sediment to settle in sea-water of a given depth, and then the geologist may determine the area over which homogeneous mixtures may be simultaneously distributed in certain seas.

Stratification. — In regard to the internal arrangement of formations deposited in the deep sea by currents far from the land, we may infer that in them, as in deltas, there is usually a division into strata; for, in both cases, the accumulations are successive, and, for the most part, interrupted. The waste of cliffs on the British coast is almost entirely confined to the winter months; so that running waters in the sea, like those on the land, are periodically charged with sediment, and again become pure.

CHAPTER X.

IGNEOUS CAUSES.

Changes of the inorganic world, *continued* — Igneous causes — Division of the subject — Distinct volcanic regions — Region of the Andes — System of volcanos extending from the Aleutian isles to the Molucca and Sunda islands — Polynesian archipelago — Volcanic region extending from Central Asia to the Azores — Former connection of the Caspian, Lake Aral, and Sea of Azof — Tradition of deluges on the shores of the Bosporus, Hellespont, and Grecian isles — Periodical alternation of earthquakes in Syria and Southern Italy — Western limits of the European region — Earthquakes rarer and more feeble as we recede from the centres of volcanic action — Extinct volcanos not to be included in lines of active vents.

WE have hitherto considered the changes wrought, since the times of history and tradition, by the continued action of aqueous causes on the earth's surface ; and we have next to examine those resulting from igneous agency. As the rivers and springs on the land, and the tides and currents in the sea, have, with some slight modifications, been fixed and constant to certain localities from the earliest periods of which we have any records, so the volcano and the earthquake have, with few exceptions, continued, during the same lapse of time, to disturb the same regions. But as there are signs, on almost every part of our continent, of great power having been exerted by running water on the surface of the land, and by waves, tides,

and currents on cliffs bordering the sea, where, in modern times, no rivers have excavated, and no waves or tidal currents undermined—so we find signs of volcanic vents and violent subterranean movements in places where the action of fire has long been dormant. We can explain why the intensity of the force of aqueous causes should be developed in succession in different districts. Currents, for example, tides, and the waves of the sea, cannot destroy coasts, shape out or silt up estuaries, break through isthmuses, and annihilate islands, form shoals in one place, and remove them from another, without the direction and position of their destroying and transporting power becoming transferred to new localities. Neither can the relative levels of the earth's crust, above and beneath the waters, vary from time to time, as they are admitted to have varied at former periods, and as it will be demonstrated that they still do, without the continents being, in the course of ages, modified, and even entirely altered, in their external configuration. Such events must clearly be accompanied by a complete change in the volume, velocity, and direction of the streams and land floods to which certain regions give passage. That we should find, therefore, cliffs where the sea once committed ravages, and from which it has now retired—estuaries where high tides once rose, but which are now dried up—valleys hollowed out by water, where no streams now flow, is no more than we should expect ; — these and similar phenomena are the necessary consequences of physical causes now in operation ; and, if there be no instability in the laws of nature, similar fluctuations must recur again and again in time to come.

But, however natural it may be that the force of

running water in numerous valleys, and of tides and currents in many tracts of the sea, should now be spent, it is by no means so easy to explain why the violence of the earthquake and the fire of the volcano should also have become locally extinct, at successive periods. We can look back to the time when the marine strata, whereon the great mass of Etna rests, had no existence ; and that time is extremely modern in the earth's history. This alone affords ground for anticipating that the eruptions of Etna will one day cease.

Nec quæ sulfureis ardet fornacibus Ætna
Ignea semper erit, neque enim fuit ignea semper,
(OVID. *Metam.* lib. 15—340.)

are the memorable words which are put into the mouth of Pythagoras by the Roman poet, and they are followed by speculations as to the cause of volcanic vents shifting their positions. Whatever doubts the philosopher expresses as to the nature of these causes, it is assumed, as incontrovertible, that the points of eruption will hereafter vary, *because they have formerly done so.*

I have endeavoured to show, in former chapters, that this principle of reasoning has been too much set at naught by some modern schools of geology, which not only refuse to conclude that great revolutions in the earth's surface are now in progress, or that they will take place hereafter, *because* they have often been repeated in former ages, but even assume the improbability of such a conclusion, and throw the whole weight of proof on those by whom that doctrine is embraced.

Division of the subject. — Volcanic action may be defined to be “the influence exerted by the heated interior of the earth on its external covering.” If we adopt this definition, without connecting it, as Humboldt has done, with the theory of secular refrigeration, or the cooling down of an original heated and fluid nucleus, we may then class under a general head all the subterranean phenomena, whether of volcanos, or earthquakes, or those insensible movements of the land, by which, as will afterwards appear, large districts may be depressed or elevated, without convulsions. According to this view, I shall consider first, the volcano; secondly, the earthquake; thirdly, the rising or sinking of land in countries where there are no volcanos or earthquakes; fourthly, the probable *causes* of the changes which result from subterranean agency.

It is a very general opinion, that earthquakes and volcanos have a common origin; for both are confined to certain regions, although the subterranean movements are least violent in the immediate proximity of volcanic vents, especially where the discharge of aërisform fluids and melted rock is made constantly from the same crater. But as there are particular regions, to which both the points of eruption and the movements of great earthquakes are confined, I shall begin by tracing out the geographical boundaries of some of these, that the reader may be aware of the magnificent scale on which the agency of subterranean fire is now simultaneously developed. Over the whole of the vast tracts alluded to, active volcanic vents are distributed at intervals, and most commonly arranged in a linear direction. Throughout the intermediate spaces there is abundant evidence that the

subterranean fire is at work continuously, for the ground is convulsed from time to time by earthquakes; gaseous vapours, especially carbonic acid gas, are disengaged plentifully from the soil; springs often issue at a very high temperature, and their waters are usually impregnated with the same mineral matters as are discharged by volcanos during eruptions.

VOLCANIC REGIONS.

Region of the Andes.—Of these great regions, that of the Andes of South America is one of the best defined, extending from the southward of Chili to the northward of Quito, from about lat. 43° S. to about 2° N. of the equator. In this range, however, comprehending forty-five degrees of latitude, there is an alternation on a grand scale of districts of active with those of extinct volcanos, or which, if not spent, have at least been dormant for the last three centuries. How long an interval of rest may entitle us to consider a volcano as entirely extinct is not easily determined; but we know that in Ischia there intervened between two consecutive eruptions a pause of seventeen centuries; and the discovery of America is an event of far too recent a date to allow us even to conjecture whether different portions of the Andes, nearly the whole of which are subject to earthquakes, may not experience alternately a cessation and renewal of eruptions. For different sets of vents may reciprocally relieve each other in the office of affording an escape to the imprisoned gases and lava, and we shall afterwards see that such periodical alternations have actually been observed in countries with which we have been longer acquainted.

The first line of active vents which have been seen in eruption in the Andes extends from lat. $43^{\circ} 28'$ S., or, from Yantales, opposite the isle of Chiloe, to Coquimbo, in lat. 30° S.; to these thirteen degrees of eruptions succeed more than eight degrees of latitude in which no volcanic action has been traced. We then come to the volcanos of Bolivia and Peru, reaching six degrees from S. to N., or from lat. 21° S. to lat. 15° S. Between the Peruvian volcanos and those of Quito, another space intervenes of no less than fourteen degrees of latitude, said to be free from volcanic action so far as yet known. The volcanos of Quito then succeed, beginning about 100 geographical miles south of the equator, and continuing for about 130 miles north of the line, when there occurs another undisturbed interval of more than six degrees of latitude, after which we arrive at the volcanos of Guatemala or Central America, north of the Isthmus of Panama.* Having thus traced out the line from south to north, I shall first state, in regard to the numerous vents of Chili, that the volcanos of Yantales and Osorno were in eruption during the great earthquake of 1835 at the same moment that the land was shaken in Chiloe, and in some parts of the Chilian coast permanently upheaved; whilst at Juan Fernandez, at the distance of no less than 720 geographical miles from Yantales, an eruption took place beneath the sea. Some of the volcanos of Chili are of great height, as that of Antuco, in lat. $37^{\circ} 40'$ S., the summit of which is at least 16,000 feet

* At the end of Von Buch's Description of the Canary Islands (Paris ed. 1836) will be found a valuable sketch of the position and characteristic phenomena of the principal volcanos of the globe, compiled with great care, and critical discrimination; a source of information of which I have largely availed myself.

above the sea. From the flanks of this volcano, at a great height, immense currents of lava have issued, one of which flowed in the year 1828. This event is said to be an exception to the general rule; few volcanos in the Andes, and none of those in Quito, having been seen in modern times to pour out lava, but having merely ejected vapour or scoriae.

Both the basaltic (or augitic) lavas, and those of the felspathic class, occur in Chili and other parts of the Andes, but the volcanic rocks of the felspathic family are said by Von Buch to be generally not trachyte, but a rock which has been called andesite, or a mixture of augite and albite. The last mentioned mineral contains soda instead of the potash found in common felspar.

The volcano of Rancagua, lat. $34^{\circ} 15' S.$, is said to be always throwing out ashes and vapours like Stromboli, a proof of the permanently heated state of certain parts of the interior of the earth below. The volcano of Maypo, lat. $33^{\circ} 53' S.$, on a plain near the base of which pumice and obsidian are found, has a cone surrounded by enormous beds of gypsum and dolomite. Lower down, at the height of 9000 feet, are strata of limestone containing fossil shells, some of which are described as identical in species with those found in the Jura limestone of Swabia.*

A year rarely passes in Chili without some slight shocks of earthquakes, and in certain districts not a month. Those shocks which come from the side of the ocean are the most violent, and the same is said to be the case in Peru. The town of Copiapo has been laid waste by this terrible scourge in the years 1773,

* Von Buch, p. 471.

1796, and 1819, or in both cases after regular intervals of twenty-three years. There have, however, been other shocks in that country in the periods intervening between the dates above mentioned, although probably all less severe, at least on the exact site of Copiapo. The evidence against a regular recurrence of volcanic convulsions at stated periods is so strong as a general fact, that we must be on our guard against attaching too much importance to a few striking but probably accidental coincidences. Among these last might be adduced the case of Lima, violently shaken by an earthquake on the 17th of June, 1578, and again on the very same day, 1678; or the eruptions of Coseguina in the years 1709 and 1809, which are the only two recorded of that volcano previous to that of 1835.*

Of the permanent upheaval of land after earthquakes in Chili, I shall have occasion to speak in the next chapter, when it will also be seen that great shocks often coincide with eruptions, either submarine, or from the cones of the Andes, showing the identity of the force which elevates continents with that which causes volcanic outbursts.†

The space between Chili and Peru, in which no volcanic action has been observed, is 160 nautical leagues from south to north. It is, however, as Von Buch observes, that part of the Andes which is least known, being thinly peopled, and in some parts entirely desert. The volcanos of Peru rise from a lofty platform to vast heights above the level of the sea, from 17,000 to 20,000 feet. The lava which has issued

* Darwin's Geol. Trans., 2d series, vol. v. p. 612.

† Ibid. p. 606.

from Viejo, lat. $16^{\circ} 55'$ S., accompanied by pumice, is composed of a mixture of crystals of albitic felspar, hornblende, and mica, a rock which has been considered as one of the varieties of andesite. Some tremendous earthquakes which have visited Peru in modern times will be mentioned in a subsequent chapter.

In regard to the district before alluded to, between Peru and Quito, extending through fourteen degrees of latitude, which is said to be entirely destitute of active volcanos, our information is extremely defective. Secondary sandstones and limestones containing ammonites reach here to the highest crest of the chain; but this fact alone is by no means conclusive of the non-volcanic character of these mountains, for the same has been observed in Central Chili, at the height of 15,000 feet, in mountains where there are active vents. The volcanos of Quito, occurring between the second degree of south and the third degree of north latitude, rise to vast elevations above the sea, many of them being between 14,000 and 18,000 feet high. The Indians of Lican have a tradition that the mountain called L'Altar, or Capac Urcu, which means "the chief," was once the highest of those near the equator, being higher than Chimborazo; but in the reign of Ouainia Abomatha, before the discovery of America, a prodigious eruption took place, which lasted eight years, and broke it down. The fragments of trachyte, says M. Boussingault, which once formed the conical summit of this celebrated mountain, are at this day spread over the plain.* Cotopaxi is the most lofty of all the South American volcanos which have been in a state of activity in modern times, its height being

* Bull. de la Soc. Géol. tom. vi. p. 55.

18,858 feet ; and its eruptions have been more frequent and destructive than those of any other mountain. It is a perfect cone, usually covered with an enormous bed of snow, which has, however, been sometimes melted suddenly during an eruption ; as in January 1803, for example, when the snows were dissolved in one night.

Deluges are often caused in the Andes by the liquefaction of great masses of snow, and sometimes by the rending open, during earthquakes, of subterranean cavities filled with water. In these inundations, fine volcanic sand, loose stones, and other materials which the water meets with in its descent, are swept away, and a vast quantity of mud, called "moya," is thus formed and carried down into the lower regions. Mud derived from this source descended, in 1797, from the sides of Tunguragua in Quito, and filled valleys a thousand feet wide to the depth of six hundred feet, forming barriers by which rivers were dammed up, and lakes occasioned. In these currents and lakes of moya thousands of small fish are sometimes enveloped, which, according to Humboldt, have lived and multiplied in subterranean cavities. So great a quantity of these fish were ejected from the volcano of Imbaburu in 1691, that fevers, which prevailed at the period, were attributed to the effluvia arising from the putrid animal matter.

In Quito, many important revolutions in the physical features of the country are said to have resulted, within the memory of man, from the earthquakes by which it has been convulsed. M. Boussingault declares his belief, that if a full register had been kept of all the convulsions experienced here and in other populous districts of the Andes, it would be found that the

trembling of the earth had been incessant. The frequency of the movement, he thinks, is not due to volcanic explosions, but to the continual falling in of masses of rock which have been fractured and upheaved in a solid form at a comparatively recent epoch ; but a longer series of observations would be requisite to confirm this opinion. According to the same author, the height of several mountains of the Andes has diminished in modern times.*

The great crest or cordillera of the Andes lowers itself at the Isthmus of Panama to the height of about 1000 feet, and even at the lowest point of separation between the two seas to 600 feet. What some geographers regard as a continuation of that chain in Central America lies to the east of a series of volcanos, many of which are active in the provinces of Pasto, Popayan, and Guatemala. Coseguina, on the south side of the Gulf of Fonseca, was in eruption in January 1835, and some of its ashes fell at Truxillo, on the shores of the Gulf of Mexico. What is still more remarkable, on the same day, at Kingston in Jamaica, the same shower of ashes fell, having been carried by an upper counter current against the regular east wind which was then blowing. Kingston is about 700 miles distant from Coseguina, and these ashes must have been more than four days in the air, having travelled 170 miles a day. Eight leagues to the southward of the crater, the ashes covered the ground to the depth of three yards and a half, destroying the fine woods and dwellings. Thousands of cattle perished, their bodies being in many instances one mass of scorched flesh. Deer and other wild animals sought the towns

* Bull. de la Soc. Géol. de France, tom. vi. p. 56.

for protection ; many birds and quadrupeds were found suffocated in the ashes, and the neighbouring streams were strewed with dead fish.* Such facts throw light on geological monuments, for in the ashes thrown out at remote periods from the spent volcanos of Auvergne, we find the bones and skeletons of extinct species of quadrupeds.

Mexico.—The great volcanic chain, after having thus pursued its course for several thousand miles from south to north, sends off a branch in a new direction in Mexico, in the parallel of the city of that name, and is prolonged in a great platform, between the eighteenth and twenty-second degrees of north latitude. This high table-land is said to owe its present form to the circumstance of an ancient system of valleys, in a chain of granitic mountains, having been filled up to the depth of many thousand feet with various volcanic products. Five active volcanos traverse Mexico from west to east—Tuxtla, Orizaba, Popocatepetl, Jurullo, and Colima. Jurullo, which is in the centre of the great platform, is no less than 120 miles from the nearest ocean—an important circumstance, as showing that the proximity of the sea is not a necessary condition, although certainly a very general characteristic, of the position of active volcanos. The extraordinary eruption of this mountain, in 1759, will be described in the sequel. If the line which connects these five vents be prolonged in a westerly direction, it cuts the volcanic group of islands called the Isles of Revillagigedo.

To the north of Mexico there are said to be three, or according to some five, volcanos in the peninsula of California ; and a volcano is reported to have been in

* Caldcleugh, Phil. Trans. 1836, p. 27.

eruption on the N. W. coast of America, near the Colombia river, lat. $45^{\circ} 37' N.$

West Indies.—To return to the Andes of Quito: Von Buch inclines to the belief, that if we were better acquainted with the region to the east of the Madalena, and with New Granada and the Caraccas, we might find the volcanic chain of the Andes to be connected with that of the West Indian, or Caribbee Islands.

Of these islands there are two parallel series, the one to the west, which are all volcanic, and which rise to the height of several thousand feet; the others to the east, for the most part composed of calcareous rocks, and very low. In the former, or volcanic series, are Granada, St. Vincent, St. Lucia, Martinique, Dominica, Guadalupe, Montserrat, Nevis, and St. Eustace. In the calcareous chain are Tobago, Barbadoes, Mariegallante, Grandeterre, Desirade, Antigua, Barbuda, St. Bartholomew, and St. Martin. The most considerable eruptions in modern times have been those of St. Vincent. Great earthquakes have agitated St. Domingo, as will be seen in the seventeenth chapter.

I have before mentioned the violent earthquakes which in 1812 convulsed the valley of the Mississippi at New Madrid, for the space of 300 miles in length. This happened exactly at the same time as the great earthquake of Caraccas, so that it is possible that these two points are parts of one volcanic region. The island of Jamaica, with a tract of the contiguous sea, has often experienced tremendous shocks; and these are frequent along a line extending from Jamaica to St. Domingo, and Porto Rico.

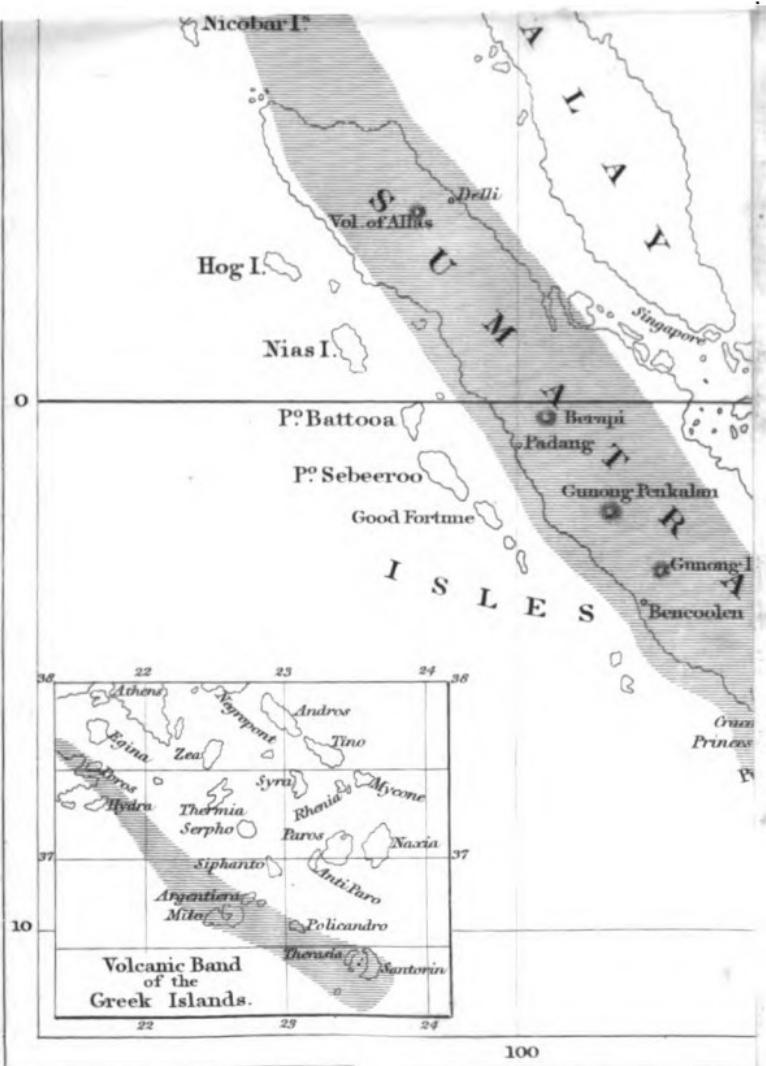
Thus it will be seen that, without taking account of the West Indian and Mexican branches, a linear train of volcanos and tracts shaken by earthquakes may be

traced from the island of Chiloe and opposite coast to Mexico, or even perhaps to the mouth of the Colombia river — a distance upon the whole as great as from the pole to the equator. In regard to the western limits of the region, they lie deep beneath the waves of the Pacific, and must continue unknown to us. On the east they are not prolonged, except where they include the West Indian Islands, to a great distance; for there seem to be no indications of volcanic disturbances in Buenos Ayres, Brazil, and the United States of North America.

Canada.—Although no volcanos have been discovered in the northern regions of the new continent, we have authentic accounts of frequent earthquakes in Canada, and some of considerable violence have occurred, as that of 1663, hereafter to be described. A large part of the estuary of the St. Lawrence and the surrounding country has been shaken from time to time ; and we learn from Captain Bayfield's Memoirs, that along the shores of the estuary and gulf of St. Lawrence, horizontal banks of recent shells appear at various heights, from ten to one hundred feet above high-water mark, and inland beaches of sand and shingle with similar shells, as also elevated limestone rocks scooped out by the waves, and showing lines of lithodomous perforations,—facts which indicate most clearly the successive upheaving of the land since the sea was inhabited by the existing species of testacea.*

Volcanic region from the Aleutian Isles to the Moluccas and Isles of Sunda.—On a scale, which equals, or surpasses, that of the Andes, is another continuous line

* Proceedings of Geol. Soc. No. 33. p. 5., and Trans. of Lit. Soc. of Quebec, vols. i. ii.



of volcanic action, which commences, on the north, with the Aleutian Isles in Russian America, and extends, first in a westerly direction for nearly 200 geographical miles, and then southwards, without interruption, throughout a space of between sixty and seventy degrees of latitude to the Moluccas, where it sends off a branch to the south-east, while the principal train continues westerly through Sumbawa and Java to Sumatra, and then in a north-westerly direction to the Bay of Bengal.* This volcanic line, observes Von Buch, may be said to follow throughout its course the external border of the continent of Asia; while the branch which has been alluded to as striking south-east from the Moluccas, passes from New Guinea to New Zealand, conforming, though somewhat rudely, to the outline of Australia.† The northern extremity of this volcanic region is on the borders of Cook's Inlet, north-east of the Peninsula of Alaska, where one volcano, in about the sixtieth degree of latitude, is said to be 14,000 feet high. In Alaska itself are cones of vast height, which have been seen in eruption, and which are covered for two thirds of their height downwards with perpetual snow. The summit of the loftiest peak is truncated, having fallen in during an eruption in 1786.

From Alaska the line is continued through the Aleutian or Fox Islands to Kamtschatka. In the Aleutian Archipelago eruptions are frequent, and about thirty miles to the north of Unalaska, near the Isle of Umnack, a new island was formed in 1796. It was first observed after a storm, at a point in the sea from which a column of smoke had been seen to rise.

* See map of volcanic lines, which I have reduced and corrected from Von Buch's work on the Canaries.

† Von Buch, *ibid.* p. 409.

Flames then issued from the new islet which illuminated the country for ten miles round ; a frightful earthquake shook the new-formed cone, and showers of stones were thrown as far as Umnack. The eruption continued for several months, and eight years afterwards, in 1804, when it was explored by some hunters, the soil was so hot in some places that they could not walk on it. According to Langsdorf and others, this new island, which is now several thousand feet high, and two or three miles in circumference, has been continually found to have increased in size when successively visited by different travellers ; but we have no accurate means of determining how much of its growth, if any, has been due to upheaval, or how far it has been exclusively formed by the ejection of ashes and streams of lava. It seems, however, to be well attested that earthquakes of the most terrific description agitate and alter the bed of the sea and surface of the land throughout this tract.

The line is continued in the southern extremity of the Peninsula of Kamtschatka, where there are many active volcanos, which, in some eruptions, have scattered ashes to immense distances. The largest and most active of these is Klutschew, lat. $56^{\circ} 3'$ N. which rises at once from the sea to the prodigious height of 15,000 feet. Within 700 feet of the summit, Erman saw, in 1829, a current of lava, emitting a vivid light, flow down the north-west side to the foot of the cone. A flow of lava from the summit of Mont Blanc to its base in the valley of Chamouni would afford but an inadequate idea of the height from which this current descended. Large quantities of ice and snow opposed for a time a barrier to the lava, until at length the fiery torrent overcame, by its heat and pressure, this ob-

stacle, and poured down the mountain side with a frightful noise, which was heard for a distance of more than fifty miles.*

The Kurile chain of islands constitutes the prolongation of the range, where a train of volcanic mountains, nine of which are known to have been in eruption, trends in a southerly direction. In these, and in the bed of the adjoining sea, alterations of level have resulted from earthquakes since the middle of the last century. The line is then continued to the southwest in the great island of Jesso, where there are active volcanic vents, as also in Nipon, the principal of the Japanese group, where the number of burning mountains is very great; slight shocks of earthquakes being almost incessant, and violent ones experienced at distant intervals.

In Jedo, in 1783, an eruption of Alamo destroyed twenty-three villages by the showers of ashes and inundations of rivers which it caused. A great number of cones were thrown up on the same line, showing clearly that they followed one cleft in the mountain. Fusi, the loftiest mountain in Japan, a little south of Jedo, is nearly as high as the Peak of Teneriffe (12,000 feet), covered with perpetual snow, emitting vapours, and formerly flames. The falling in of part of this mountain is said to have happened before the Christian era; and so late as 1793, Unsen, another volcano farther to the south, fell in and caused a deep hollow, from which dense vapours issued, and an eruption and earthquakes followed, in which 53,000 persons perished.†

Between the Japanese and Phillipine Islands, the

* Von Buch, *Descrip. des Iles Canar.* p. 450., who cites Erman and others.

† *Ibid.* p. 440.

communication is preserved by several small insular vents. Sulphur Island, in the Loo Choo Archipelago, emits sulphureous vapour; and Formosa suffers greatly from earthquakes. In Luzon, the most northern and largest of the Philippines, are three active volcanos; Sanguil, a volcano in Mindinao, was also in eruption in 1764. The line is then prolonged through Sangir and the north-eastern extremity of Celebes, by Ternate and Tidore, to the Moluccas. The chain of volcanos then sends off a branch by New Guinea, in a south-easterly direction towards New Zealand, while, as before stated, another branch bends round to the west, and is prolonged through Sumbawa to the Sunda Islands. I shall first pursue the western branch. We have records of several streams of lava which have issued from the principal mountain in Banda; and it is stated that, in 1820, after an eruption, a solid mass, composed of large blocks of basalt, was raised out of the sea and filled up a great bay on the eastern side of the island, which had previously a depth of sixty fathoms. The mass rose so as to form hills, yet was not in a state of fusion, superficially at least, but disengaged vapours from fissures without the ejection of pumice or scoriæ. Von Buch infers from Reinwardt's Narrative, that, in this instance, beds of volcanic matter were upraised into a dome-shaped form.* The great eruption of Tomboro in Sumbawa, in 1815, will be mentioned in the fifteenth chapter.

There are said to be thirty-eight considerable volcanos in Java, some of which are more than 10,000 feet high. They are remarkable for the quantity of sulphur and sulphureous vapours which they discharge.

* Von Buch, *Descrip. des Iles Canar.* p. 413.

They rarely emit lava, but rivers of mud issue from them, like the moya of the Andes of Quito. The memorable eruption of Galongoon, in 1822, will be described in the thirteenth chapter. The crater of Taschem, at the eastern extremity of Java, contains a lake of sulphuric acid, a quarter of a mile long, from which a river of acid water issues, which supports no living creature, nor can fish live in the sea near its confluence. There is an extinct crater near Batur, called Guevo Upas, or the Valley of Poison, about half a mile in circumference, which is justly an object of terror to the inhabitants of the country. Every living being which penetrates into this valley falls down dead, and the soil is covered with the carcasses of tigers, deer, birds, and even the bones of men; all killed by the abundant emanations of carbonic acid gas, by which the bottom of the valley is filled.

In another crater in this land of wonders, near the volcano of Talaga Bodas, we learn from Mr. Reinwardt, that the sulphureous exhalations have killed tigers, birds, and innumerable insects; and the soft parts of these animals, such as the fibres, muscles, nails, hair, and skin, are very well preserved, while the bones are corroded and entirely destroyed.

The same linear arrangement which is observed in Java holds good in the volcanos of Sumatra, some of which are of great height, as Berapi, which is more than 12,000 feet above the sea, and is continually smoking. Hot springs are abundant at its base. The volcanic line then inclines slightly to the north-west, and points to Barren Island, lat. $12^{\circ} 15' N.$, in the Bay of Bengal. This volcano was in eruption in 1792, and will be described in the fourteenth chapter. The volcanic train then extends, according to Dr. MacClelland,

to the island of Narcondam, lat. $13^{\circ} 22'$ N., which is a cone seven or eight hundred feet high, rising from deep water, and said to present signs of lava currents descending from the crater to the base. Afterwards the train stretches in the same direction to the volcanic island of Rambree, about lat. 19° N., and the adjoining island of Cheduba, which is represented in old charts as a burning mountain. Thus we arrive at the Chittagong coast, which in 1762 was convulsed by a tremendous earthquake (see chap. xvii.).*

To return now to the branch before mentioned as striking off from the Moluccas in a south-easterly direction, we find the volcanic band at first prolonged through part of New Guinea, and then continued by Admiralty Islands, New Britain, and Saloman's Islands to New Zealand. On the east of New Britain is a volcano, from which Dampier saw, in 1700, a current of incandescent lava flow down to the sea. In New Zealand, in lat. 37° S., an active volcano, called White Island, has lately been discovered.

To enumerate all the volcanic regions of the Indian and Pacific oceans would lead me far beyond the proper limits of this treatise, but it will appear in the last chapter of the third volume, when coral reefs are treated of, that the islands of the Pacific consist alternately of linear groups of two classes, the one lofty, and containing active volcanos, and marine strata above the sea-level, and which have been undergoing upheaval in modern times; the other very low, consisting of reefs of coral, usually with lagoons in their centres, and in which there is evidence of a gradual subsidence of the ground.

* MacClelland, Report on Coal and Min. Resources of India. Calcutta, 1838.

Volcanic region from Central Asia to the Azores. — Another great region of subterranean disturbance is that which extends through a large part of Central Asia to the Azores, or from China and Tartary through Lake Aral and the Caspian to the Caucasus, and the countries bordering the Black Sea, then again through part of Asia Minor to Syria, and westward to the Grecian islands, Greece, Naples, Sicily, the southern part of Spain, Portugal, and the Azores. Respecting the eastern extremity of this line in China, we have but little information, although many violent earthquakes are known to have occurred in that country. The volcano said to have been in eruption in the seventh century in Central Tartary is situated on the northern declivity of the Celestial Mountains, not far distant from the large lake called Issikoul, and Humboldt mentions other vents and solfataras in the same quarter, which are all worthy of notice, as being far more distant from the ocean (260 geographical miles) than any other known points of eruption.

We find on the western shores of the Caspian, in the country round Baku, a tract called the Field of Fire, which continually emits inflammable gas, while springs of naphtha and petroleum occur in the same vicinity, as also mud volcanos. In the chain of Elburs, to the south of this sea, is a lofty mountain, which, according to Morier, sometimes emits smoke, and at the base of which are several small craters, where sulphur and saltpetre are procured in sufficient abundance to be used in commerce. Violent subterranean commotions have been experienced along the borders of the Caspian ; and, according to Engelhardt and Parrot, the bottom of that sea has, in modern times, varied in form ; and, according to them, near the south

coast, the Isle of Idak, north from Astrabat, formerly high land, has now become very low.*

The steppes of the Caspian, or plains covered with recent shells, and terminated by shingle beaches and lines of inland cliffs, point to former alterations in the relative level of land and sea; and Pallas has endeavoured to show that an ancient strait, by which the Caspian was once united to the Sea of Azof, is still indicated by a low tract of sand.

In the country between the Caspian and the Black seas, and in the chain of Caucasus, numerous earthquakes have, in modern times, caused fissures and subsidences of the soil, especially at Tiflis.† The Caucasian territories abound in hot-springs and mineral waters. So late as 1814, a new island was raised by volcanic explosions in the Sea of Azof; and Pallas mentions that, in the same locality, opposite old Temruk, a submarine eruption took place in 1799, accompanied with dreadful thundering, emission of fire and smoke, and the throwing up of mire and stones. Violent earthquakes were felt at the same time at great distances from Temruk. The country around Erzerum exhibits similar phenomena.

Syria and Palestine abound in volcanic appearances, and very extensive areas have been shaken, at different periods, with great destruction of cities and loss of lives. Continual mention is made in history of the ravages committed by earthquakes in Sidon, Tyre, Berytus, Laodicea, and Antioch, and in the Island of Cyprus. The country around the Dead Sea appears evidently, from the accounts of modern travellers, to

* Travels in the Crimea and Caucasus, in 1815, vol. i. pp. 257. 264.—Von Hoff, vol. i. p. 137.

† Von Hoff, vol. ii. p. 210.

be volcanic. A district near Smyrna, in Asia Minor, was termed by the Greeks Catacecaumene, or the burnt, where there is a large arid territory, without trees, and with a cindery soil.*

Grecian Archipelago. — Proceeding westwards, we reach the Grecian Archipelago, where Santorin, afterwards to be described, is the grand centre of volcanic action. To the north-west of Santorin is another volcano in the Island of Milo, of recent aspect, having a very active solfatara in its central crater, and many sources of boiling water and steam. Continuing the same line, we arrive at that part of the Morea where we learn, from ancient writers, that Helice and Bura were, in the year 373 B. C., submerged beneath the sea by an earthquake; and the walls, according to Ovid, were to be seen beneath the waters. Near the same spot, in our times (1817), Vostizza was laid in ruins by a subterranean convulsion.† At Methone, also (now Modon), in Messenia, about three centuries before our era, an eruption threw up a great volcanic mountain, which is represented by Strabo as being nearly 4000 feet in height; but the magnitude of the hill requires confirmation. Some suppose that the accounts of the formation of a hill near Troezene, of which the date is unknown, may refer to the same event.

It was Von Buch's opinion that the volcanos of Greece were arranged in a line running N. N. W: and S. S. E., as represented in the map, Pl. 6.; and that they afforded the only example in Europe of active volcanos having a linear direction ‡; but M. Virlet, on the contrary, announces as the result of his invest-

* Strabo, ed. Fal., p. 900.

† Von Hoff, vol. ii. p. 172.

‡ See plate of volcanic bands, p. 130.

igations, made during the late French expedition to the Morea, that there is no one determinate line of direction for the volcanic phenomena in Greece, whether we follow the points of eruptions, or the earthquakes, or any other signs of igneous agency.*

Macedonia, Thrace, and Epirus, have always been subject to earthquakes, and the Ionian Isles are continually convulsed.

Traditions of Deluges. — The traditions which have come down to us from remote ages of great inundations said to have happened in Greece and on the confines of the Grecian settlements, had doubtless their origin in a series of local catastrophes, caused principally by earthquakes. The frequent migrations of the earlier inhabitants, and the total want of written annals long after the first settlement of each country, make it impossible for us at this distance of time to fix either the true localities or probable dates of these events. The first philosophical writers of Greece were, therefore, as much at a loss as ourselves to offer a reasonable conjecture on these points, or to decide how many catastrophes might sometimes have become confounded in one tale, or how much this tale may have been amplified, in after times, or obscured by mythological fiction. The floods of Ogyges and Deucalion are commonly said to have happened before the Trojan war; that of Ogyges more than seventeen, and that of Deucalion more than fifteen centuries before Christ. As to the Ogygian flood, it is generally described as having laid waste Attica, and was referred by some writers to a great overflowing of rivers, to which cause Aristotle also attributed the deluge of Deucalion, which, he says,

* Virlet, *Bulletin de la Soc. Géol. de France*, tom. iii. p. 109.

affected Hellas only, or the central part of Thessaly. Others imagined the same event to have been due to an earthquake, which threw down masses of rock, and stopped up the course of the Peneus in the narrow defile between mounts Ossa and Olympus.

As to the deluge of Samothrace, which is generally referred to a distinct date, it appears that the shores of that small island and the adjoining mainland of Asia were inundated by the sea. Diodorus Siculus says that the inhabitants had time to take refuge in the mountains, and save themselves by flight; he also relates, that long after the event, the fishermen of the island drew up in their nets the capitals of columns, "which were the remains of cities submerged by that terrible catastrophe." * These statements scarcely leave any doubt that there occurred, at the period alluded to, a subsidence of the coast, accompanied by earthquakes and inroads of the sea. It is not impossible that the story of the bursting of the Black Sea through the Thracian Bosphorus into the Grecian Archipelago, which accompanied, and, as some say, caused the Samothracian deluge, may have reference to a wave, or succession of waves, raised in the Euxine by the same convulsion.

We know that subterranean movements and volcanic eruptions are often attended not only by incursions of the sea, but also by violent rains, and the complete derangement of the river drainage of the inland country, and by the damming up of the outlets of lakes by landslips, or obstructions in the courses of subterranean rivers, such as abound in Thessaly and the Morea. We need not therefore be surprised at the

* Book v. ch. xlvi. — See Letter of M. Virlet *Bulletin de la Soc. Géol. de France*, tom. ii. p. 341.

variety of causes assigned for the traditional floods of Greece, by Herodotus, Aristotle, Diodorus, Strabo, and others. As to the area embraced, had all the Grecian deluges occurred simultaneously, instead of being spread over many centuries, and had they, instead of being extremely local, reached at once from the Euxine to the south-western limit of the Peloponnes, and from Macedonia to Rhodes, the devastation would still have been more limited than that which visited Chili in 1835, when a volcanic eruption broke out in the Andes, opposite Chiloe, and another at Juan Fernandez, distant 720 geographical miles, at the same time that several lofty cones in the Cordillera, 400 miles to the eastward of that island, threw out vapour and ignited matter. Throughout a great part of the space thus recently shaken in South America, cities were laid in ruins, or the land was permanently upheaved, or mountainous waves rolled inland from the Pacific.

Respecting Southern Italy, Sicily, and the Lipari Isles, it is unnecessary to enlarge here, as I shall have occasion again to allude to them. I may mention, however, that a band of volcanic action has been traced by Dr. Daubeny across the Italian Peninsula, from Ischia to Mount Vultur, in Apulia, the commencement of the line being found in the hot springs of Ischia, after which it is prolonged through Vesuvius to the Lago d'Ansanto, where gases similar to those of Vesuvius are evolved. Its farther extension strikes Mount Vultur, a lofty cone composed of tuff and lava, from one side of which carbonic acid and sulphuretted hydrogen are emitted.*

* Daubeny on Mount Vultur, Ashmolean Memoirs. Oxford, 1835.

Periodical alternation of Earthquakes in Syria and Southern Italy. — It has been remarked by Von Hoff, that from the commencement of the thirteenth to the latter half of the seventeenth century, there was an almost entire cessation of earthquakes in Syria and Judea ; and, during this interval of quiescence, the Archipelago, together with part of the adjacent coast of Lesser Asia, as also Southern Italy and Sicily, suffered greatly from earthquakes ; while volcanic eruptions were unusually frequent in the same regions. A more extended comparison, also, of the history of the subterranean convulsions of these tracts seems to confirm the opinion, that a violent crisis of commotion never visits both at the same time. It is impossible for us to declare, as yet, whether this phenomenon is constant in this and other regions, because we can rarely trace back a connected series of events farther than a few centuries ; but it is well known that, where numerous vents are clustered together within a small area, as in many archipelagos for instance, two of them are never in violent eruption at once. If the action of one becomes very great for a century or more, the others assume the appearance of spent volcanos. It is, therefore, not improbable that separate provinces of the same great range of volcanic fires may hold a relation to one deep-seated focus, analogous to that which the apertures of a small group bear to some more superficial rent or cavity. Thus, for example, we may conjecture that, at a comparatively small distance from the surface, Ischia and Vesuvius mutually communicate with certain fissures, and that each affords relief alternately to elastic fluids and lava there generated. So we may suppose Southern Italy and Syria to be connected, at a much greater depth, with a lower part of the very same system

of fissures ; in which case any obstruction occurring in one duct may have the effect of causing almost all the vapour and melted matter to be forced up the other, and if they cannot get vent, they may be the cause of violent earthquakes.

The north-eastern portion of Africa, including Egypt, which lies six or seven degrees south of the volcanic line already traced, has been almost always exempt from earthquakes : but the north-western portion, especially Fez and Morocco, which fall within the line, suffer greatly from time to time. The southern part of Spain also, and Portugal have generally been exposed to the same scourge simultaneously with Northern Africa. The provinces of Malaga, Murcia, and Granada, and in Portugal the country round Lisbon, are recorded at several periods to have been devastated by great earthquakes. It will be seen, from Michell's account of the great Lisbon shock in 1755, that the first movement proceeded from the bed of the ocean ten or fifteen leagues from the coast. So late as February 2. 1816, when Lisbon was vehemently shaken, two ships felt a shock in the ocean west from Lisbon ; one of them at the distance of 120, and the other 262 French leagues from the coast * — a fact which is the more interesting, because a line drawn through the Grecian Archipelago, the volcanic region of Southern Italy, Sicily, Southern Spain, and Portugal, will, if prolonged westward through the ocean, strike the volcanic group of the Azores, which has therefore, in all probability, a submarine connection with the European line. How far the island of Ma-

* Verneur, *Journal des Voyages*, tom. iv. p. 111.—Von Hoff, vol. ii. p. 275.

deira, which has been subject to violent earthquakes, and the Canary Islands, in which volcanic eruptions have been frequent, may communicate beneath the waters with the same great region, must for the present be mere matter of conjecture.

In regard to the volcanic system of Southern Europe, it may be observed, that there is a central tract where the greatest earthquakes prevail, in which rocks are shattered, mountains rent, the surface elevated or depressed, and cities laid in ruins. On each side of this line of greatest commotion there are parallel bands of country, where the shocks are less violent. At a still greater distance (as in Northern Italy, for example, extending to the foot of the Alps), there are spaces where the shocks are much rarer and more feeble, yet possibly of sufficient force to cause, by continued repetition, some appreciable alteration in the external form of the earth's crust. Beyond these limits, again, all countries are liable to slight tremors at distant intervals of time, when some great crisis of subterranean movement agitates an adjoining volcanic region; but these may be considered as mere vibrations, propagated mechanically through the external covering of the globe, as sounds travel almost to indefinite distances through the air. Shocks of this kind have been felt in England, Scotland, Northern France, and Germany—particularly during the Lisbon earthquake. But these countries cannot, on this account, be supposed to constitute parts of the southern volcanic region, any more than the Shetland and Orkney islands can be considered as belonging to the Icelandic circle, because the sands ejected from Hecla have been wafted thither by the winds.

Besides the continuous spaces of subterranean disturbance, of which we have merely sketched the outline, there are other disconnected volcanic groups, of which several will be mentioned hereafter.

Lines of active and extinct Volcanos not to be confounded.—We must always be careful to distinguish between lines of extinct and active volcanos, even where they appear to run in the same direction; for ancient and modern systems may interfere with each other. Already, indeed, we have proof that this is the case; so that it is not by geographical position, but by reference to the species of organic beings alone, whether aquatic or terrestrial, whose remains occur in beds interstratified with lavas, that we can clearly distinguish the relative age of volcanos of which no eruptions are recorded. Had Southern Italy been known to civilized nations for as short a period as America, we should have had no record of eruptions in Ischia; yet we might have assured ourselves that the lavas of that isle had flowed since the Mediterranean was inhabited by the species of testacea now living in the Neapolitan seas. With this assurance, it would not have been rash to include the numerous vents of that island in the modern volcanic group of Campania.

On similar grounds we may infer, without much hesitation, that the eruptions of Etna, and the modern earthquakes of Calabria, are a continuation of that action which, at a somewhat earlier period, produced the submarine lavas of the Val di Noto in Sicily. But, on the other hand, the lavas of the Euganean hills and the Vicentin, although not wholly beyond the range of earthquakes in Northern Italy, must not be

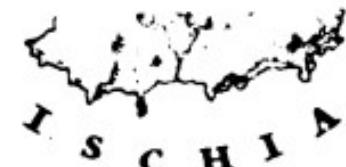
confounded with any existing volcanic system; for when they flowed, the seas were inhabited by animals almost all of them distinct from those now known to live, whether in the Mediterranean or other parts of the globe.

CHAPTER XI.

VOLCANIC DISTRICT OF NAPLES.

History of the volcanic eruptions in the district round Naples — Early convulsions in the island of Ischia — Numerous cones thrown up there — Epomeo not an habitual volcano — Lake Avernus — The Solfatara — Renewal of the eruptions of Vesuvius, A. D. 79 — Pliny's description of the phenomena — Remarks on his silence respecting the destruction of Herculaneum and Pompeii — Subsequent history of Vesuvius — Lava discharged in Ischia in 1802 — Pause in the eruptions of Vesuvius — Monte Nuovo thrown up — Uniformity of the volcanic operations of Vesuvius and the Phlegræan Fields in ancient and modern times.

I SHALL next give a sketch of the history of some of the volcanic vents dispersed throughout the great regions before described, and consider the composition and arrangement of their lavas and ejected matter. The only volcanic region known to the ancients was that of the Mediterranean ; and even of this they have transmitted to us very imperfect records relating to the eruptions of the three principal districts, namely, that round Naples, that of Sicily and its isles, and that of the Grecian Archipelago. By far the most connected series of records throughout a long period relates to the first of these provinces ; and these cannot be too attentively considered, as much historical information is indispensable in order to enable us to obtain a clear



VOLCANIC DISTRICT
OF
NAPLES.



view of the connection and alternate mode of action of the different vents in a single volcanic group.

Early convulsions in the Island of Ischia.—The Neapolitan volcanos extend from Vesuvius, through the Phlegræan Fields, to Procida and Ischia, in a somewhat linear arrangement, ranging from the north-east, to the south-west, as will be seen in the annexed map of the volcanic district of Naples (plate 7.). Within the space above limited, the volcanic force is sometimes developed in single eruptions from a considerable number of irregularly scattered points; but a great part of its action has been confined to one principal and habitual vent, Vesuvius or Somma. Before the Christian era, from the remotest periods of which we have any tradition, this principal vent was in a state of inactivity. But terrific convulsions then took place from time to time in Ischia (*Pithecura*), and seem to have extended to the neighbouring isle of Procida (*Prochyta*); for Strabo * mentions a story of Procida having been torn asunder from Ischia; and Pliny † derives its name from its having been poured forth by an eruption from Ischia.

The present circumference of Ischia along the water's edge is eighteen miles, its length from west to east about five, and its breadth from north to south three miles. Several Greek colonies which settled there before the Christian era were compelled to abandon it in consequence of the violence of the eruptions. First the Erythræans, and afterwards the Chalcidians, are mentioned as having been driven out by earthquakes and igneous exhalations. A colony was afterwards established by Hiero, king of Syracuse,

* Lib. v.

† Nat. Hist. lib. iii. c. 6.

about 380 years before the Christian era; but when they had built a fortress, they were compelled by an eruption to fly, and never again returned. Strabo tells us that Timæus recorded a tradition, that, a little before his time, Epomeus, the principal mountain in the centre of the island, vomited fire during great earthquakes; that the land between it and the coast had ejected much fiery matter, which flowed into the sea, and that the sea receded for the distance of three stadia, and then returning, overflowed the island. This eruption is supposed by some to have been that which formed the crater of Monte Corvo on one of the higher flanks of Epomeo, above Foria, the lava-current of which may still be traced, by aid of the scoriæ on its surface, from the crater to the sea.

To one of the subsequent eruptions in the lower parts of the isle, which caused the expulsion of the first Greek colony, Monte Rotaro has been attributed, and it bears every mark of recent origin. The cone is remarkably perfect, and has a crater on its summit precisely resembling that of Monte Nuovo near Naples; but the hill is larger, and resembles some of the more considerable cones of single eruption near Clermont in Auvergne, and, like some of them, it has given vent to a lava-stream at its base, instead of its summit. A small ravine swept out by a torrent exposes the structure of the cone, which is composed of innumerable inclined and slightly undulating layers of pumice, scoriæ, white lapilli, and enormous angular blocks of trachyte. These last have evidently been thrown out by violent explosions, like those which in 1822 launched from Vesuvius a mass of augitic lava, of many tons weight, to the distance of three miles, which fell in the garden of Prince Ottajano. The cone of Rotaro

is covered with the arbutus, and other beautiful evergreens. Such is the strength of the virgin soil, that the shrubs have become almost arborescent; and the growth of some of the smaller wild plants has been so vigorous, that botanists have scarcely been able to recognize the species.

The eruption which dislodged the Syracusan colony is supposed to have given rise to that mighty current which forms the promontory of Zaro and Caruso. The surface of these lavas is still very arid and bristling, and is covered with black scoriae; so that it is not without great labour that human industry has redeemed some small spots, and converted them into vineyards. Upon the produce of these vineyards the population of the island is almost entirely supported. It amounts at present to about twenty-five thousand, and is on the increase.

From the date of the great eruption last alluded to, down to our own time, Ischia has enjoyed tranquillity, with the exception of one emission of lava hereafter to be described, which, although it occasioned much local damage, does not appear to have devastated the whole country, in the manner of more ancient explosions. There are, upon the whole, on different parts of Epomeo, or scattered through the lower tracts of Ischia, twelve considerable volcanic cones, which have been thrown up since the island was raised above the surface of the deep; and many streams of lava may have flowed, like that of "Arso" in 1302, without cones having been produced; so that this island may, for ages before the period of the remotest traditions, have served as a safety-valve to the whole Terra di Lavoro, while the fires of Vesuvius were dormant.

Lake Avernus.—It seems also clear that Avernus,

a circular lake near Puzzuoli, about half a mile in diameter, which is now a salubrious and cheerful spot, once exhaled mephitic vapours, such as are often emitted by craters after eruptions. There is no reason for discrediting the account of Lucretius, that birds could not fly over it without being stifled, although they may now frequent it uninjured.* There must have been a time when this crater was in action ; and for many centuries afterwards it may have deserved the appellation of “*atri janua Ditis*,” emitting, perhaps, gases as destructive of animal life as those suffocating vapours given out by Lake Quilotoa, in Quito, in 1797, by which whole herds of cattle on its shores were killed †, or as those deleterious emanations which annihilated all the cattle in the island of Lancerote, one of the Canaries, in 1730.‡ Bory St. Vincent mentions, that in the same isle birds fell lifeless to the ground ; and Sir William Hamilton informs us that he picked up dead birds on Vesuvius during an eruption.

Solfatara.—The Solfatara, near Puzzuoli, which may be considered as a nearly extinguished crater, appears, by the accounts of Strabo and others, to have been before the Christian era in very much the same state as at present, giving vent continually to aqueous vapour, together with sulphureous and muriatic acid gases, like those evolved by Vesuvius.

Ancient history of Vesuvius.—Such, then, were the

* De Rerum Nat. vi. 740.—Forbes, on Bay of Naples, Edin. Journ. of Sci., No. iii., new series, p. 87. Jan. 1830.

† Humboldt, Voy., p. 317.

‡ Von Buch, *Über einen vulcanischen Ausbruch auf der Insel Lanzarote*.

points where the subterranean fires obtained vent, from the earliest period to which tradition reaches back, down to the first century of the Christian era; but we then arrive at a crisis in the volcanic action of this district—one of the most interesting events witnessed by man during the brief period throughout which he has observed the physical changes on the earth's surface. From the first colonization of Southern Italy by the Greeks, Vesuvius afforded no other indications of its volcanic character than such as the naturalist might infer, from the analogy of its structure to other volcanos. These were recognized by Strabo, but Pliny did not include the mountain in his list of active vents. The ancient cone was of a very regular form, terminating, not as at present, in two peaks, but with a flatish summit, where the remains of an ancient crater, nearly filled up, had left a slight depression, covered in its interior by wild vines, and with a sterile plain at the bottom. On the exterior, the flanks of the mountains were clothed with fertile fields richly cultivated, and at its base were the populous cities of Herculaneum and Pompeii. But the scene of repose was at length doomed to cease, and the volcanic fire was recalled to the main channel, which, at some former unknown period had given passage to repeated streams of melted lava, sand, and scoriæ.

Renewal of its eruptions.—The first symptom of the revival of the energies of this volcano was the occurrence of an earthquake in the year 63 after Christ, which did considerable injury to the cities in its vicinity. From that time to the year 79 slight shocks were frequent; and in the month of August of that year they became more numerous and violent, till they ended at length in an eruption. The elder Pliny, who

commanded the Roman fleet, was then stationed at Misenum; and in his anxiety to obtain a near view of the phenomena, he lost his life, being suffocated by sulphureous vapours. His nephew, the younger Pliny, remained at Misenum, and has given us, in his Letters, a lively description of the awful scene. A dense column of vapour was first seen rising vertically from Vesuvius, and then spreading itself out laterally, so that its upper portion resembled the head, and its lower the trunk of the pine, which characterizes the Italian landscape. This black cloud was pierced occasionally by flashes of fire as vivid as lightning, succeeded by darkness more profound than night. Ashes fell even upon the ships at Misenum, and caused a shoal in one part of the sea—the ground rocked, and the sea receded from the shores, so that many marine animals were seen on the dry sand. The appearances above described agree perfectly with those witnessed in more recent eruptions, especially those of Monte Nuovo in 1538, and of Vesuvius in 1822.

Silence of Pliny respecting the destruction of Herculaneum and Pompeii.—In all times and countries, indeed, there is a striking uniformity in the volcanic phenomena; but it is most singular that Pliny, although giving a circumstantial detail of so many physical facts, and describing the eruption, earthquake, and shower of ashes which fell at Stabiæ, makes no allusion to the sudden overwhelming of two large and populous cities, Herculaneum and Pompeii. All naturalists who have searched into the memorials of the past for records of physical events, must have been surprised at the indifference with which the most memorable occurrences are often passed by, in the works of writers of enlightened periods; as also of the extraordinary ex-

aggeration which usually displays itself in the traditions of similar events, in ignorant and superstitious ages. But no omission is more remarkable than that now under consideration: nor has the circumstance been at all explained by the suggestion that the chief object of the younger Pliny was to give Tacitus a full account of the particulars of his uncle's death. Had the buried cities never been discovered, the accounts transmitted to us of their tragical end would have been discredited by the majority, so vague and general are the narratives, or so long subsequent to the event. Tacitus, the friend and contemporary of Pliny, when advertiring in general terms to the convulsions, says merely that "cities were consumed or buried."*

Suetonius, although he alludes to the eruption incidentally, is silent as to the cities. They are mentioned by Martial, in an epigram, as immersed in cinders; but the first historian who alludes to them by name is Dion Cassius†, who flourished about a century and a half after Pliny. He appears to have derived his information from the traditions of the inhabitants, and to have recorded, without discrimination, all the facts and fables which he could collect. He tells us, "that during the eruption a multitude of men of superhuman stature, resembling giants, appeared, sometimes on the mountain, and sometimes in the environs—that stones and smoke were thrown out, the sun was hidden, and then the giants seemed to rise again, while the sounds of trumpets were heard, &c. &c.; and finally," he relates, "two entire cities, Herculaneum and Pompeii, were buried under showers of ashes, while all the

* Haustæ aut obrutæ urbes. — Hist. lib. i.

† Hist. Rom. lib. lxvi.

people were sitting in the theatre." That many of these circumstances were invented, would have been obvious, even without the aid of Pliny's letters; and the examination of Herculaneum and Pompeii enables us to prove, that none of the people were destroyed in the theatres, and, indeed, that there were very few of the inhabitants who did not escape from both cities. Yet some lives were lost, and there was ample foundation for the tale in its most essential particulars.

This case may often serve as a caution to the geologist, who has frequent occasion to weigh, in like manner, negative evidence derived from the silence of eminent writers, against the obscure but positive testimony of popular traditions. Some authors, for example, would have us call in question the reality of the Ogygian deluge, because Homer and Hesiod say nothing of it. But they were poets, not historians, and they lived many centuries after the latest date assigned to the catastrophe. Had they even lived at the time of that flood, we might still contend that their silence ought, no more than Pliny's, to avail against the authority of tradition, however much exaggeration we may impute to the traditional narrative of the event.

It does not appear that in the year 79 any lava flowed from Vesuvius; the ejected substances, perhaps, consisted entirely of lapilli, sand, and fragments of older lava, as when Monte Nuovo, was thrown up in 1538. The first era at which we have authentic accounts of the flowing of a stream of lava, is the year 1036, which is the seventh eruption from the revival of the fires of the volcano. A few years afterwards, in 1049, another eruption is mentioned, and another in 1138 (or 1139), after which a great pause ensued

of 168 years. During this long interval of repose, two minor vents opened at distant points. First, it is on tradition that an eruption took place from the Solfatara in the year 1198, during the reign of Frederic II., Emperor of Germany; and although no circumstantial detail of the event has reached us from those dark ages, we may receive the fact without hesitation.* Nothing more, however, can be attributed to this eruption, as Mr. Scrope observes, than the discharge of a light and scoriform trachytic lava, of recent aspect, resting upon the strata of loose tuff which covers the principal mass of trachyte.†

Volcanic eruption in Ischia, 1302. — The other occurrence is well authenticated,— the eruption, in the year 1302, of a lava-stream from a new vent on the south-east side of the Island of Ischia. During part of 1301, earthquakes had succeeded one another with fearful rapidity; and they terminated at last with the discharge of a lava-stream from a point named the Campo del Arso, not far from the town of Ischia. This lava ran quite down to the sea — a distance of about two miles; in colour it varies from iron grey to reddish black, and is remarkable for the glassy felspar which it contains. Its surface is almost as sterile, after a period of five centuries, as if it had cooled down yesterday. A few scantlings of wild thyme, and two or three other dwarfish plants, alone appear in the interstices of the scoriæ, while the Vesuvian lava of 1767 is already covered with a luxuriant vegetation. Pontanus, whose country-house was burnt and over-

* The earliest authority, says Mr. Forbes, given for this fact, appears to be Capaccio, quoted in the *Terra Tremante* of Bonito.— *Edin. Journ. of Sci. &c.*, No. i., new series, p. 127. July, 1829.

† *Geol. Trans.*, second series, vol. ii. p. 346.

whelmed, describes the dreadful scene as having lasted two months.* Many houses were swallowed up, and a partial emigration of the inhabitants followed. This eruption produced no cone, but only a slight depression, hardly deserving the name of a crater, where heaps of black and red scoriæ lie scattered around. Until this eruption, Ischia is generally believed to have enjoyed an interval of rest for about seventeen centuries; but Julius Obsequens†, who flourished A.D. 214, refers to some volcanic convulsions in the year 662 after the building of Rome (91 b.c.). As Pliny, who lived a century before Obsequens, does not enumerate this among other volcanic eruptions, the statement of the latter author is supposed to have been erroneous; but it would be more consistent, for reasons before stated, to disregard the silence of Pliny, and to conclude that some kind of subterranean commotion, probably of no great violence, happened at the period alluded to.

History of Vesuvius after 1138. — To return to Vesuvius: — the next eruption occurred in 1306; between which era and 1631 there was only one other (in 1500), and that a slight one. It has been remarked, that throughout this period Etna was in a state of such unusual activity as to lend countenance to the idea that the great Sicilian volcano may sometimes serve as a channel of discharge to elastic fluids and lava that would otherwise rise to the vents in Campania.

Formation of Monte Nuovo, 1538. — The great pause was also marked by a memorable event in the Phlegræan Fields — the sudden formation of a new moun-

* Lib. vi. de Bello Neap. in Grævii Thesaur.

† Prodig. libel. c. cxiv.

tain in 1538, of which we have received authentic accounts from contemporary writers.

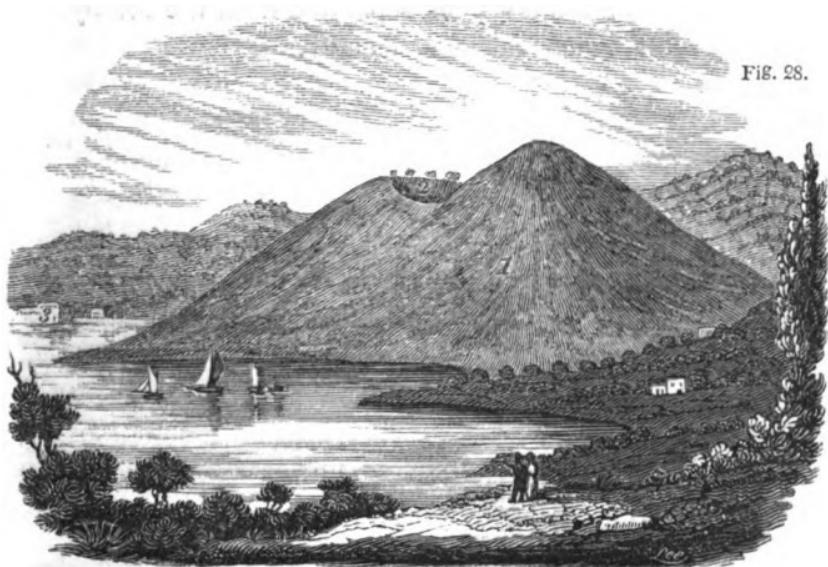


Fig. 28.

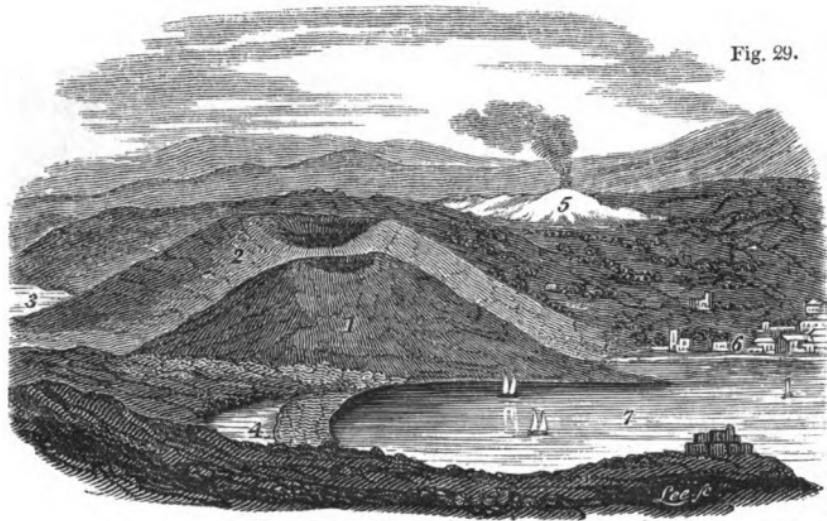
Monte Nuovo, formed in the Bay of Baiae, Sept. 29th, 1538.

- 1, Cone of Monte Nuovo. 2, Brim of crater of ditto.
3, Thermal spring, called Baths of Nero, or Stufe di Tritoli.

The height of Monte Nuovo has recently been determined, by the Italian mineralogist Pini, to be 440 English feet above the level of the bay; its base is about eight thousand feet, or more than a mile and a half, in circumference. According to Pini, the depth of the crater is 421 English feet from the summit of the hill, so that its bottom is only nineteen feet above the level of the sea. The cone is declared, by the best authorities, to stand partly on the site of the Lucrine Lake (4, fig. 29.*), which was nothing more than the crater

* This representation of the Phlegræan Fields is reduced from part of Plate xxxi. of Sir William Hamilton's great work, "Campi Phlegræi." The faithfulness of his coloured delineations of the scenery of that country cannot be too highly praised.

of a pre-existent volcano, and was almost entirely filled during the explosion of 1538. Nothing now remains but a shallow pool, separated from the sea by an elevated beach, raised artificially.



The Phlegræan Fields.

- | | |
|-------------------|-------------------|
| 1, Monte Nuovo. | 4, Lucrine Lake. |
| 2, Monte Barbaro. | 5, The Solfatara. |
| 3, Lake Avernua. | 6 Puzzuoli. |
| 7. Bay of Baiae. | |

Sir William Hamilton has given us two original letters describing this eruption. The first, by Falconi, dated 1538, contains the following passages.* “It is now two years since there have been frequent earthquakes at Puzzuoli, Naples, and the neighbouring parts. On the day and in the night before the eruption (of Monte Nuovo), above twenty shocks, great and small, were felt. The eruption began on the 29th of September, 1538. It was on a Sunday, about one o'clock in the night, when flames of fire were seen

* *Campi Phlegræi*, p. 70.

between the hot baths and Tripertola. In a short time the fire increased to such a degree, that it burst open the earth in this place, and threw up so great a quantity of ashes and pumice stones, mixed with water, as covered the whole country. The next morning (after the formation of Monte Nuovo) the poor inhabitants of Puzzuoli quitted their habitations in terror, covered with the muddy and black shower which continued the whole day in that country—flying from death, but with death painted in their countenances. Some with their children in their arms, some with sacks full of their goods; others leading an ass, loaded with their frightened family, towards Naples; others carrying quantities of birds, of various sorts, that had fallen dead at the beginning of the eruption; others, again, with fish which they had found, and which were to be met with in plenty on the shore, the sea having left them dry for a considerable time. I accompanied Signor Moramaldo to behold the wonderful effects of the eruption. The sea had retired on the side of Baiae, abandoning a considerable tract, and the shore appeared almost entirely dry, from the quantity of ashes and broken pumice stones thrown up by the eruption. I saw two springs in the newly discovered ruins; one before the house that was the queen's, of hot and salt water," &c.

So far Falconi; the other account is by Pietro Giacomo di Toledo, which begins thus:—" It is now two years since this province of Campagna has been afflicted with earthquakes, the country about Puzzuoli much more so than any other parts: but the 27th and the 28th of the month of September last, the earthquakes did not cease day or night in the town of Puzzuoli: that plain which lies between Lake Avernus,

the Monte Barbaro, and the sea, was *raised a little*, and many cracks were made in it, from some of which issued water; at the same time the sea immediately adjoining the plain *dried up about two hundred paces*, so that the fish were left on the sand a prey to the inhabitants of Puzzuoli. At last, on the 29th of the same month, about two o'clock in the night, the earth opened near the lake, and discovered a horrid mouth, from which were vomited furiously smoke, fire, stones, and mud, composed of ashes, making at the time of its opening a noise like the loudest thunder. The stones which followed were by the flames converted to pumice, and some of these were *larger than an ox*. The stones went about as high as a cross-bow can carry, and then fell down, sometimes on the edge, and sometimes into the mouth itself. The mud was of the colour of ashes, and at first very liquid, then by degrees less so, and in such quantities, that in less than twelve hours, with the help of the above-mentioned stones, a mountain was raised of 1000 paces in height. Not only Puzzuoli and the neighbouring country was full of this mud, but the city of Naples also; so that many of its palaces were defaced by it. Now this eruption lasted two nights and two days without intermission, though, it is true, not always with the same force; the third day the eruption ceased, and I went up with many people to the top of the new hill, and saw down into its mouth, which was a round cavity about a quarter of a mile in circumference, in the middle of which the stones which had fallen were boiling up, just as a caldron of water boils on the fire. The fourth day it began to throw up again, and the seventh much more, but still with less violence than the first night. At this time many persons who were

on the hill were knocked down by the stones and killed, or smothered with the smoke. In the day the smoke still continues, and you often see fire in the midst of it in the night-time." *

It will be seen that both these accounts, written immediately after the birth of Monte Nuovo, agree in stating that the sea retired; and one mentions that its bottom was upraised; but they attribute the origin of the new hill exclusively to the jets of mud, showers of scoriæ, and large fragments of rock, cast out from a central orifice for several days and nights. Baron Von Buch, however, in his excellent work on the Canary Islands, and volcanic phenomena in general, has declared his opinion that the cone and crater of Monte Nuovo were formed, not in the manner above described, but by the upheaval of solid beds of white tuff, which were previously horizontal, but which were pushed up in 1538, so as to dip away in all directions from the centre, with the same inclination as the sloping surface of the cone itself. "It is an error," he says, "to imagine that this hill was formed by eruption, or by the ejection of pumice, scoriæ, and other incoherent matter; for the solid beds of upraised tuff are visible all round the crater, and it is merely the superficial covering of the cone which is made up of ejected scoriæ.†

In confirmation of this view, M. Dufrénoy has recently cited a passage from the works of Porzio, a celebrated physician of that period, to prove that in 1538 the ground where Monte Nuovo stands was pushed up in the form of a great bubble or blister, which on bursting, gave origin to the present deep crater. Porzio says, "that after two days and nights of

* *Campi Phlegræi*, p. 77.

† P. 347. Paris, 1836.

violent earthquakes, the sea retired for nearly 200 yards; so that the inhabitants could collect great numbers of fish on this part of the shore, and see some springs of fresh water which rose up there. At length, on the third day of the calends of October (September 29th), they saw a large tract of ground intervening between the foot of Monte Barbaro and part of the sea, near the Lake Avernus, rise, and suddenly assume the form of an incipient hill; and at two o'clock at night, this heap of earth, opening as it were its mouth, vomited, with a loud noise, flames, pumice stones, and ashes." *

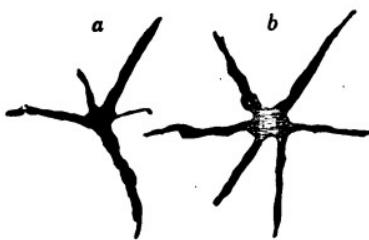
On considering the more detailed accounts of the eye-witnesses Falconi and Toledo, I am inclined to believe that on the night of the 29th, a gulf opened between Tripertogola and the baths in its suburbs, and that mud, pumice, and large solid blocks of stone were discharged from the chasm, so as to bury the town, and throw up a considerable hill in less than twenty-four hours, in the same manner as on a smaller scale the mud cones of air volcanos are produced, with a cavity in the middle. There is no difficulty in conceiving that the pumiceous mud, if so thrown out, may have set into a kind of stone on drying, just as some cements, composed of volcanic ashes, are known.

* " Magnus terræ tractus, qui inter radices montis, quem Barbarum incolæ appellant, et mare juxta Avernus jacet, sese erigere videbatur, et montis subito nascentis figuram imitari. Eo ipso die horâ noctis II., iste terræ cumulus, aperto veluti ore, magno cum fremitu, magnos ignes evomuit; pumicesque, et lapides, cineresque." — Porzio, *Opera Omnia, Medica, Phil., et Mathemat.*, in unum collecta, 1796, cited by Dufrénoy, *Mém. pour servir à une Description Géologique de la France*, tom. iv. p. 274.

to consolidate with facility. Tripergola was much frequented as a watering place, and contained an hospital for those who resorted there for the benefit of the thermal springs ; and it appears that there were no fewer than three inns in the principal street. Had Porzio stated that any of these buildings, or the ruins of them, were seen by himself or others raised up above the plain, a short time before the first eruption, so as to stand on the summit or slope of a newly-raised hillock, we might have been compelled, by so circumstantial a narrative, to adopt M. Dufrénoy's interpretation.

But in the absence of such evidence, we must appeal to the crater itself, where we behold a section of the whole mountain, without being able to detect any original nucleus of upheaved rock distinct from the rest; on the contrary, the whole mass is similar throughout in composition, and the cone very symmetrical in form ; nor are there any clefts, such as might be looked for as the effect of the sudden up-throw of stony masses. M. C. Prevost has well remarked, that if beds of solid and non-elastic materials had yielded to a violent pressure directed from below upwards, we should find not simply a deep empty

Fig. 30.



cavity, but an irregular opening, where many rents converged; and these rents would be now seen breaking through the walls of the crater, widening as they approach the centre. (See fig. 30. *a, b.*)* Not

* *Mém. de la Soc. Géol. de France, tom. ii. p. 91.*

a single fissure of this kind is observable in the interior of Monte Nuovo, where the walls of the crater are continuous and entire; nor are there any dikes implying that rents had existed, which were afterwards filled with lava or other matter.

It has moreover been often urged by Von Buch, De Beaumont, and others, who ascribe the conical form of volcanos chiefly to upheaval from below, that in such mountains there are a great number of deep rents and ravines, which diverge on all sides like the spokes of a wheel, from near the central axis to the circumference or base of the cone, as in the case of Palma, Cantal, and Teneriffe. Yet the entire absence of such divergent fissures or ravines, in such cases as Monte Nuovo, Somma, or Etna, is passed by unnoticed, and appears to have raised in their minds no objection to their favourite theory.

It is, indeed, admitted by M. Dufrénoy that there are some facts which it is very difficult to reconcile with his own view of Porzio's record. Thus, for example, there are certain Roman monuments at the base of Monte Nuovo, and on the borders of Lake Avernus, such as the temples of Apollo and Pluto, which do not seem to have suffered in the least degree by the supposed upheaval. "The walls which still exist have preserved their vertical position, and the vaults are in the same state as other monuments on the shores of the Bay of Baiæ. The long gallery which led to the Sibyl's Cave, on the other side of Lake Avernus, has in like manner escaped injury, the roof of the gallery remaining perfectly horizontal, the only change being that the soil of the chamber in which the Sibyl gave out her oracles is now covered by a few

inches of water, which merely indicates a slight alteration in the level of Lake Avernus."* On the supposition, then, that pre-existing beds of pumiceous tuff were upraised in 1538, so as to form Monte Nuovo, it is acknowledged that the perfectly undisturbed state of the contiguous soil on which these ancient monuments stand, is very different from what might have been expected.

I shall again revert to the doctrine of the origin of volcanic cones by upheaval, when speaking of Vesuvius and Etna, and I shall now merely add, that in 1538, the whole coast, from Monte Nuovo to beyond Puzzuoli, was upraised to the height of many feet above the bed of the Mediterranean, and has since retained the greater part of the elevation then acquired. The proofs of these remarkable changes of level will be considered at length when the phenomena of the Temple of Serapis are described.†

Volcanos of the Phlegræan Fields. — Immediately adjoining Monte Nuovo is the larger volcanic cone of Monte Barbaro (2. fig. 29.), the Gaurus inanis of Juvenal — an appellation given to it probably from its deep circular crater, which is about a mile in diameter. Large as is this cone, it was probably produced by a single eruption; and it does not, perhaps, exceed in magnitude some of the largest of those formed in Ischia, within the historical era. It is composed chiefly of indurated tufa like Monte Nuovo, stratified conformably to its conical surface. This hill was once very celebrated for its wines, and is still covered with vineyards; but when the vine is not in leaf it has a sterile appearance, and, late in the year, when seen

* Dufrénoy, *Mém. pour servir, &c.* p. 277. † See chap. xvii.

from the beautiful bay of Baiæ, it often contrasts so strongly in verdure with Monte Nuovo, which is always clothed with arbutus, myrtle, and other wild evergreens, that a stranger might well imagine the cone of older date to be that thrown up in the sixteenth century.*

There is nothing, indeed, so calculated to instruct the geologist as the striking manner in which the recent volcanic hills of Ischia; and that now under consideration, blend with the surrounding landscape. Nothing seems wanting or redundant ; every part of the picture is in such perfect harmony with the rest, that the whole has the appearance of having been called into existence by a single effort of creative power. Yet what other result could we have anticipated, if Nature has ever been governed by the same laws ? Each new mountain thrown up — each new tract of land raised or depressed by earthquakes — should be in perfect accordance with those previously formed, if the entire configuration of the surface has been due to a long series of similar disturbances. Were it true that the greater part of the dry land originated simultaneously in its present state, at some era of paroxysmal convulsion, and that additions were afterwards made slowly and successively during a period of comparative repose ; then, indeed, there might be reason to expect a strong line of demarcation between the signs of ancient and modern changes. But the very continuity of the plan, and the perfect identity of the causes, are to many a source of decep-

* Hamilton (writing in 1770) says, "the new mountain produces as yet but a very slender vegetation." — *Campi Phlegræi*, p. 69. This remark was no longer applicable when I saw it, in 1828.

tion ; since, by producing a unity of effect, they lead them to exaggerate the energy of the agents which operated in the earlier ages. In the absence of all historical information, they are as unable to separate the dates of the origin of different portions of our continents, as the stranger is to determine, by their physical features alone, the distinct ages of Monte Nuovo, Monte Barbaro, Astroni, and the Solfatara.

The vast scale and violence of the volcanic operations in Campania, in the olden time, has been a theme of declamation, and has been contrasted with the comparative state of quiescence of this delightful region in the modern era. Instead of inferring, from analogy, that the ancient Vesuvius was always at rest when the craters of the Phlegræan Fields were burning, — that each cone rose in succession, — and that many years, and often centuries, of repose intervened between different eruptions, — geologists seem to have generally conjectured that the whole group sprung up from the ground at once, like the soldiers of Cadmus when he sowed the dragon's teeth. As well might they endeavour to persuade us that on these Phlegræan Fields, as the poets feigned, the giants warred with Jove, ere yet the puny race of mortals were in being.

Modern eruptions of Vesuvius. — For nearly a century after the birth of Monte Nuovo, Vesuvius continued in a state of tranquillity. There had then been no violent eruption for 492 years ; and it appears that the crater was then exactly in the condition of the present extinct volcano of Astroni, near Naples. Bracini, who visited Vesuvius not long before the eruption of 1631, gives the following interesting description of the interior : — “ The crater was five miles in circumference, and about a thousand paces deep ; its sides

were covered with brushwood, and at the bottom there was a plain on which cattle grazed. In the woody parts wild boars frequently harboured. In one part of the plain, covered with ashes, were three small pools, one filled with hot and bitter water, another salter than the sea, and a third hot, but tasteless." * But at length these forests and grassy plains were consumed, being suddenly blown into the air, and their ashes scattered to the winds. In December, 1631, seven streams of lava poured at once from the crater, and overflowed several villages on the flanks and at the foot of the mountain. Resina, partly built over the ancient site of Herculaneum, was consumed by the fiery torrent. Great floods of mud were as destructive as the lava itself,—no uncommon occurrence during these catastrophes; for such is the violence of rains produced by the evolution of aqueous vapour, that torrents of water descend the cone, and, becoming charged with impalpable volcanic dust, and rolling along loose ashes, acquire sufficient consistency to deserve their ordinary appellation of "aqueous lavas."

A brief period of repose ensued, which lasted only until the year 1666, from which time to the present there has been a constant series of eruptions, with rarely an interval of rest exceeding ten years. During these three centuries, no irregular volcanic agency has convulsed other points in this district. Brieslak remarked, that such irregular convulsions had occurred in the Bay of Naples in every second century; as, for example, the eruption of the Solfatara, in the twelfth, of the lava of Arso, in Ischia, in the fourteenth, and of

* Hamilton's *Campi Phlegræi*, folio, vol. i. p. 62.; and Brieslak, *Campanie*, tome i. p. 186.

Monte Nuovo in the sixteenth : but the eighteenth has formed an exception to this rule, and this seems accounted for by the unprecedented number of eruptions of Vesuvius during that period ; whereas, when the new vents opened, there had always been, as we have seen, a long intermittance of activity in the principal volcano.

CHAPTER XII.

VOLCANIC DISTRICT OF NAPLES — *continued.*

Dimensions and structure of the cone of Vesuvius — Dikes — Lavas and minerals — Alluviums called “aqueous lavas” — Origin and composition of the matter enveloping Herculaneum and Pompeii — Condition and contents of the buried cities — Small number of skeletons — State of preservation of animal and vegetable substances — Rolls of papyrus — Stabiæ — Torre del Greco — Concluding remarks on the Campanian volcanos.

Structure of the cone of Vesuvius. — BETWEEN the end of the eighteenth century and the year 1822, the great crater of Vesuvius had been gradually filled by lava boiling up from below, and by scoriæ falling from the explosions of minor mouths which were formed at intervals on its bottom and sides. In place of a regular cavity, therefore, there was a rough and rocky plain, covered with blocks of lava and scoriæ, and cut by numerous fissures, from which clouds of vapour were evolved. But this state of things was totally changed by the eruption of October, 1822, when violent explosions, during the space of more than twenty days, broke up and threw out all this accumulated mass, so as to leave an immense gulf or chasm, of an irregular, but somewhat elliptical shape, about three miles in circumference when measured along the very sinuous and irregular line of its extreme margin, but somewhat

less than three quarters of a mile in its longest diameter, which was directed from N. E. to S. W.* The depth of this tremendous abyss has been variously estimated; for from the hour of its formation it decreased daily by the dilapidation of its sides. It measured, at first, according to the account of some authors, two thousand feet in depth from the extreme part of the existing summit †; but Mr. Scrope, when he saw it, soon after the eruption, estimated its depth at less than half that amount. More than eight hundred feet of the cone was carried away by the explosions, so that the mountain was reduced in height from about 4200 to 3400 feet.‡

As we ascend the sloping sides, the volcano appears a mass of loose materials — a mere heap of rubbish, thrown together without the slightest order; but on arriving at the brim of the crater, and obtaining a view of the interior, we are agreeably surprised to discover that the conformation of the whole displays in every part the most perfect symmetry and arrangement. The materials are disposed in regular strata, slightly undulating, appearing, when viewed in front, to be disposed in horizontal planes. But, as we make the circuit of the edge of the crater, and observe the cliffs by which it is encircled projecting or receding in saillent or retiring angles, we behold transverse sections of the currents of lava and beds of sand and scoriæ, and recognize their true dip. We then discover that

* Account of the Eruption of Vesuvius in October, 1822, by G. P. Scrope, Esq., Journ. of Sci., &c. vol. xv. p. 175.

† Mr. Forbes, Account of Mount Vesuvius, Edin. Journ. of Sci., No. xviii. p. 195. Oct. 1828.

‡ Ibid. p. 194.

they incline outwards from the axis of the cone, at angles varying from 30° to 45° . The whole cone, in fact, is composed of a number of concentric coatings of alternating lavas, sand, and scoriæ. Every shower of ashes which has fallen from above, and every stream of lava descending from the lips of the crater, have conformed to the outward surface of the hill, so that one conical envelope may be said to have been successively folded round another, until the aggregation of the whole mountain was completed. The marked separation into distinct beds results from the different colours and degrees of coarseness in the sands, scoriæ, and lava, and the alternation of these with each other. The greatest difficulty, on the first view, is to conceive how so much regularity can be produced, notwithstanding the unequal distribution of sand and scoriæ, driven by prevailing winds in particular eruptions, and the small breadth of each sheet of lava as it first flows out from the crater.

But on a closer examination, we find that the appearance of extreme uniformity is delusive, for when a number of beds thin out gradually, and at different points, the eye does not without difficulty recognize the termination of any one stratum, but usually supposes it continuous with some other, which at a short distance may lie precisely in the same plane. The slight undulations, moreover, produced by inequalities on the sides of the hill on which the successive layers were moulded, assist the deception. As countless beds of sand and scoriæ constitute the greater part of the whole mass, these may sometimes mantle continuously round the whole cone ; and even lava-streams may be of considerable breadth when first they overflow ; and, since in some eruptions, a considerable part

of the upper portion of the cone breaks down at once, may form a sheet extending as far as the space which the eye usually takes in in a single section.

The high inclination of some of the beds, and the firm union of the particles even where there is evidently no cement, is another striking feature in the volcanic tuffs and breccias, which seems at first not very easy of explanation. But the last great eruption afforded ample illustration of the manner in which these strata are formed. Fragments of lava, scoriæ, pumice, and sand, when they fall at slight distances from the summit, are only half cooled down from a state of fusion, and are afterwards acted upon by the heat from within, and by fumeroles or small crevices in the cone through which hot vapours are disengaged. Thus heated, the ejected fragments cohere together strongly ; and the whole mass acquires such consistency in a few days, that fragments cannot be detached without a smart blow of the hammer. At the same time sand and scoriæ, ejected to a greater distance, remain incoherent.*

Sir William Hamilton, in his description of the eruption of 1779, says, that jets of liquid lava, mixed with stones and scoriæ, were thrown up to the height of at least ten thousand feet, having the appearance of a column of fire.† Some of these were directed by the winds towards Ottajano, and some of them, falling almost perpendicularly, still red hot and liquid, on Vesuvius, covered its whole cone, part of the mountain of Somma, and the valley between them. The falling matter being nearly as vividly

* Monticelli and Covelli, *Storia di Fenon. del Vesuv.*, en 1821-2-3.

† *Campi Phlegræi.*

inflamed as that which was continually issuing fresh from the crater, formed with it one complete body of fire, which could not be less than two miles and a half in breadth, and of the extraordinary height above mentioned, casting a heat to the distance of at least six miles around it. Dr. Clarke, also, in his account of the eruption of 1793, says that millions of red-hot stones were shot into the air full half the height of the cone itself, and then bending, fell all round in a fine arch. On another occasion he says that, as they fell, they covered nearly half the cone with fire.

The same author has also described the different appearance of the lava at its source, and at some distance from it, when it had descended into the plains below. At the point where it issued, in 1793, from an arched chasm in the side of the mountain, the vivid torrent rushed with the velocity of a flood. It was in perfect fusion, unattended with any scoriæ on its surface, or any gross materials not in a state of complete solution. It flowed with the translucency of honey, "in regular channels, cut finer than art can imitate, and glowing with all the splendour of the sun."—"Sir William Hamilton," he continues, "had conceived that no stones thrown upon a current of lava would make any impression. I was soon convinced of the contrary. Light bodies, indeed, of five, ten, and fifteen pounds weight made little or no impression even at the source; but bodies of sixty, seventy, and eighty pounds were seen to form a kind of bed on the surface of the lava, and float away with it. A stone of three hundred weight, that had been thrown out by the crater, lay near the source of the current of lava: I raised it upon one end, and then let it fall in upon the liquid lava; when it gradually sunk

beneath the surface, and disappeared. If I wished to describe the manner in which it acted upon the lava, I should say that it was like a loaf of bread thrown into a bowl of very thick honey, which gradually involves itself in the heavy liquid, and then slowly sinks to the bottom.

"The lava, at a small distance from its source, acquires a darker tint upon its surface, is less easily acted upon, and, as the stream widens, the surface, having lost its state of perfect solution, grows harder and harder, and cracks into innumerable fragments of very porous matter, to which they give the name of scoriæ, and the appearance of which has led many to suppose that it proceeded thus from the mountain. There is, however, no truth in this. All lava, at its first exit from its native volcano, flows out in a liquid state, and all equally in fusion. The appearance of the scoriæ is to be attributed only to the action of the external air, and not to any difference in the materials which compose it, since any lava whatever, separated from its channel, and exposed to the action of the external air, immediately cracks, becomes porous, and alters its form. As we proceeded downward, this became more and more evident; and the same lava which at its original source flowed in perfect solution, undivided, and free from encumbrances of any kind, a little farther down had its surface loaded with scoriæ in such a manner, that, upon its arrival at the bottom of the mountain, the whole current resembled nothing so much as a heap of unconnected cinders from an iron-foundery." In another place he says, that "the rivers of lava in the plain resembled a vast heap of cinders, or the scoriæ of an iron-foundery, rolling

slowly along, and falling with a rattling noise over one another.”*

It appears that the intensity of the light and heat of the lava varies considerably at different periods of the same eruption, as in that of Vesuvius in 1819 and 1820, when Sir H. Davy remarked different degrees of vividness in the white heat at the point where the lava originated.†

When the expressions “flame” and “smoke” are used in describing volcanic appearances, they must generally be understood in a figurative sense. We are informed, indeed, by M. Abich that he distinctly saw, in the eruption of Vesuvius in 1834, the flame of burning hydrogen ‡; but what is usually mistaken for flame consists of vapour or scoriæ, and impalpable dust illuminated by that vivid light which is emitted from the crater below, where the lava is said to glow with the splendour of the sun. The clouds of apparent smoke are formed either of aqueous and other vapour, or of finely comminuted scoriæ.

Dikes in the recent cone, how formed. — The inclined strata before mentioned which dip outwards in all directions from the axis of the cone of Vesuvius, are intersected by veins or dikes of compact lava, for the most part in a vertical position. In 1828 these were seen to be about seven in number, some of them not less than four or five hundred feet in height, and thinning out before they reached the uppermost part of the cone. Being harder than the beds through

* Otter’s Life of Dr. Clarke.

† Phil. Trans., 1828, p. 241.

‡ Bulletin de la Soc. Géol. de France, tom. vii. p. 43.; and Illustrations of Vesuvius and Etna, p. 3.

which they pass, they have decomposed less rapidly, and therefore stand out in relief. When I visited Vesuvius, in November 1828, I was prevented from descending into the crater by the constant ejections then thrown out; so that I got sight of three only of the dikes ; but Signor Monticelli had previously had drawings made of the whole, which he showed me. The dikes which I saw were on that side of the cone which is encircled by Somma. The eruption before mentioned, of 1828, began in March, and in the November following the ejected matter had filled up nearly one third of the deep abyss formed at the close of the eruption in 1822. In November I found a single black cone at the bottom of the crater continually throwing out scoriæ, while on the exterior of the cone I observed the lava of 1822, which had flowed out six years before, not yet cool, and still evolving much heat and vapour from crevices.

Hoffmann, in 1832, saw on the north side of Vesuvius, near the peak called Palo, a great many parallel bands of lava, some from six to eight feet thick, alternating with scoriæ and conglomerate. These beds, he says, were cut through by many dikes, some of them five feet broad. They resemble those of Somma, the stone being composed of grains of leucite and augite.*

There can be no doubt that the dikes above mentioned have been produced by the filling up of open fissures with liquid lava ; but of the date of their formation we know nothing further than that they are all subsequent to the year 79, and, relatively speaking, that they are more modern than all the lavas and scoriæ which they intersect. A considerable number

* *Geognost. Beobachtungen, &c.* p. 182. Berlin, 1839.

of the upper strata are not traversed by them. That the earthquakes, which almost invariably precede eruptions, occasion rents in the mass is well known ; and, in 1822, three months before the lava flowed out, open fissures, evolving hot vapours, were numerous. It is clear that such rents must be injected with melted matter when the column of lava rises, so that the origin of the dikes is easily explained, as also the great solidity and crystalline nature of the rock composing them, which has been formed by lava cooling slowly under great pressure.

It has been suggested that the frequent rending of volcanic cones during eruptions may be connected with the gradual and successive upheaval of the whole mass in such a manner as to increase the inclination of the beds composing the cone ; and in accordance with the hypothesis before proposed for the origin of Monte Nuovo, Von Buch supposes that the present cone of Vesuvius was formed in the year 79, not by eruption, but by upheaval. It was not produced by the repeated superposition of scoriæ and lava cast out or flowing from a central source, but by the uplifting of strata previously horizontal. The entire cone rose at once, such as we now see it, from the interior and middle of Somma, and has since received no accession of height, but, on the contrary, has ever since been diminishing in elevation.*

Of the facts hitherto known, which may seem to favour this singular hypothesis of Von Buch, none are more deserving of attention than those recorded by M. Abich in his account of the Vesuvian eruptions of

* Von Buch, *Descrip. Phys. des Isles Canaries*, p. 342.
Paris, 1836.

1833 and 1834, a work illustrated by excellent engravings of the volcanic phenomena which he witnessed.* It appears that, in the year 1834, the great crater of Vesuvius had been filled up nearly to the top with lava, which had consolidated and formed a level and unbroken plain, except that a small cone thrown up by the ejection of scoriæ rose in the middle of it like an island in a lake. At length this plain of lava was broken by a fissure which passed from N. E. to S. W., and along this line a great number of minute cones emitting vapour were formed. The first act of formation of these minor cones is said to have consisted of a partial upheaval of beds of lava previously horizontal, and which had been rendered flexible by the heat and tension of elastic fluids, which rising from below, escaped from the centre of each new monticule. The analogy of this mode of origin with that ascribed by Von Buch to Vesuvius and Somma would be very perfect, if the dimensions of the upraised masses were not on so different a scale, and if it was safe to reason from the inflation of bladders of half-fused lava, from fifteen to twenty-five feet in height, to mountains attaining an altitude of several thousand feet.

At the same time M. Abich mentions, that when, in August 1834, a great subsidence took place in the platform of lava within the great crater, so that the structure of the central cone was laid open, it was seen to have been evidently formed, not by upheaval, but by the fall of cinders and scoriæ which had been thrown out during successive eruptions.†

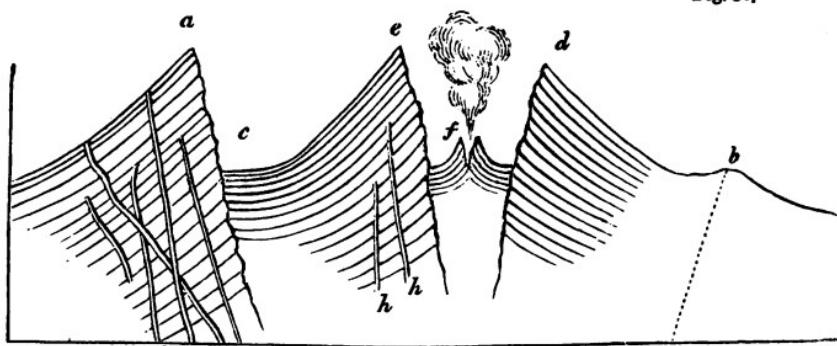
Previous to the year 79, Vesuvius appears, from the

* *Vues Illust. de Phénom. Géol. Observ. sur le Vésuve et l'Etna.* Berlin, 1837.

† *Ibid.* p. 2.

description of its figure given by Strabo, to have been a truncated cone, with a crater at its summit; and Brieslak first announced the opinion, which has since been generally adopted, that the eruptions which occurred in 79, and subsequently, destroyed that side of the original cone which was towards the sea, leaving the remainder, now called Somma, encircling a new cone, which was then first thrown up. In the annexed diagram (Fig. 31.) it will be seen that, on the side of Vesuvius opposite to that where a portion of the ancient cone of Somma (*a*) still remains, is a projection (*b*)

Fig. 31.

*Supposed section of Vesuvius and Somma.*

- a*, Monte Somma, or the remains of the ancient cone of Vesuvius.
- b*, The Pedamentina, a terrace-like projection, encircling the base of the recent cone of Vesuvius, on the south side.
- c*, Atrio del Cavallo.*
- d, e*, Crater left by eruption of 1822.
- f*, Small cone thrown up in 1828, at the bottom of the great crater.
- g, g*, Dikes intersecting Somma.
- h, h*, Dikes intersecting the recent cone of Vesuvius.

called the Pedamentina, which some have supposed to be part of the circumference of the ancient crater broken down towards the sea, and over the edge of

* So called from travellers leaving their horses and mules there when they prepare to ascend the cone on foot.

which the lavas of the modern Vesuvius have poured ; the axis of the present cone of Vesuvius being, according to Visconti, precisely equidistant from the escarpment of Somma and the Pedamentina.

In the same diagram the slanting beds of the cone of Vesuvius are represented as becoming horizontal in the Atrio del Cavallo (at *c*), where the base of the new cone meets the precipitous escarpment of Somma ; for when the lava flows down to this point, as happened in 1822, its descending course is arrested, and it then runs in another direction along this small valley, circling round the base of the cone. Sand and scoriæ, also, blown by the winds, collect at the base of the cone, and are then swept away by torrents ; so that there is always here a flattish plain, as represented. In the same manner the small interior cone (*f*) must be composed of sloping beds, terminating in a horizontal plain ; for, while this monticule was gradually gaining height by successive ejections of lava and scoriæ, in 1828, it was always surrounded by a flat pool of semi-fluid lava, into which scoriæ and sand were thrown.

In the steep semicircular escarpment of Somma, which faces the modern Vesuvius, we see a great number of sheets of lava inclined at an angle of about 26° . They alternate with scoriæ, and are intersected by numerous dikes, which, like the sheets of lava, are composed chiefly of augite, with crystals of leucite, but the rock in the dikes is more compact, having cooled and consolidated under greater pressure. Some of the dikes cut through and shift others, so that they have evidently been formed during successive eruptions. While the higher region of Somma is made up of these igneous products, there appear on its flanks, for some

depth from the surface, as seen in a ravine, called the “Fossa Grande,” beds of white pumiceous tuff, resembling the tuff which, at Pausilippo, and other places, near Naples, contains shells of living Mediterranean species. It is supposed by Pilla, Von Buch, and others, that the tufaceous beds, which rise in Somma to more than half the height of that mountain, are, in like manner, of submarine origin, because a few sea-shells have been found in them, here and there, together with serpulae of recent species attached to included blocks of limestone.*

It is contended, therefore, that, as these strata were once accumulated beneath the sea, they may have been subjected as they rose to such an upward movement as may have given rise to a conical hill; and this hypothesis, it is said, acquires confirmation from the fact, that the sheets of lava near the summit of Somma are so compact and crystalline, and of such breadth individually, as would not have been the case had they run down a steep slope. They must, therefore, have consolidated on a nearly level surface, and have been subsequently uplifted into their present inclined position.

Unfortunately there are no sections of sufficient depth and continuity on the flanks of Somma, to reveal to us clearly the relations of the lava, scoriae, and associated dikes, forming the highest part of the mountain with the marine tuffs observed on its declivity. Both may, perhaps, have been produced contemporaneously when Somma raised its head, like Stromboli,

* Dufrénoy, *Mém. pour servir à une Descrip. Géol. de la France*, tom. iv. p. 294.

above the sea, its sides and base being then submerged. Such a state of things may be indicated by a fact noticed by Von Buch, namely, that the pumiceous beds of Naples, when they approach Somma, contain fragments of the peculiar leucitic lava proper to that mountain, which are not found in the same tuff at a greater distance.* Portions, therefore, of this lava were either thrown out by explosions, or torn off by the waves, during the deposition of the pumiceous strata beneath the sea.

We have as yet but a scanty acquaintance with the laws which regulate the flow of lava beneath water, or the arrangement of scoriæ and volcanic dust on the sides of a submarine cone. There can, however, be little doubt that showers of ejected matter may settle on a steep slope, and may include shells and the remains of aquatic animals, which flourish in the intervals between eruptions. Lava under the pressure of water would be less porous, but, as Dr. Daubeny suggests, it may retain its fluidity longer than in the open air; for the rapidity with which heated bodies are cooled by being plunged into water arises chiefly from the conversion of the lower portions of water into steam, which steam absorbing much heat, immediately ascends, and is reconverted into water. But under the pressure of an ocean sufficiently deep to prevent the formation of steam, the heat of the lava would be carried off more slowly, and only by the circulation of ascending and descending currents of water, those portions nearest the source of heat becoming specifically lighter, and consequently displacing the water

* *Descrip. Phys. des Iles Canaries*, p. 344.

above. This kind of circulation would take place with much less rapidity than in the atmosphere, inasmuch as the expansion of water by equal increments of heat is less considerable than that of air.*

If we admit that the inclined position of the sheets of lava and marine tuffs on Somma may have been partly due to that rending of the cone, which is proved by the dikes to have occurred again and again, we may still believe the form of the mountain to have been principally due to eruptions from a central orifice. It is also in the highest degree probable that the development of the upheaving force, by which the shape of the cone may have been modified, was intermittent and gradual, not concentrated, as Von Buch and others have suggested, in one effort of sudden and violent convulsion.

Vesuvian lavas.—The lavas of Somma are characterized by containing disseminated crystals of leucite (called, by the French, *amphigène*), a mineral said to be very rare in the modern lavas of Vesuvius, which are in general much more scoriaceous and less crystalline than those of Somma.†

At the fortress near Torre del Greco a section is exposed, fifteen feet in height, of a current which ran into the sea; and it evinces, especially in the lower part, a decided tendency to divide into rude columns. A still more striking example may be seen to the west of Torre del Annunziata, near Forte Scassato, where the mass is laid open to the depth of twenty feet. In both these cases, however, the rock may rather be said to be divided into numerous perpen-

* See Daubeny's *Volcanos*, p. 400.

† Dufrénoy, *Mém. pour servir, &c.*, tom. iv. p. 285.

dicular fissures, than to be prismatic, although the same picturesque effect is produced. In the lava-currents of Central France (those of the Vivarais, in particular), the uppermost portion, often forty feet or more in thickness, is an amorphous mass passing downwards into lava irregularly prismatic; and under this, there is a foundation of regular and vertical columns, but these lavas are often one hundred feet or more in thickness. We can scarcely expect to discover the same phenomenon in the shallow currents of Vesuvius, where the lowest part has cooled more rapidly, although it may be looked for in modern streams in Iceland, which exceed even those of ancient France in volume.

Mr. Scrope mentions that, in the cliffs encircling the modern crater of Vesuvius, he saw many currents offering a columnar division, and some almost as regularly prismatic as any ranges of the older basalts; and he adds, that in some the spheroidal concretionary structure, on a large scale, was equally conspicuous.* Brieslak† also informs us that, in the siliceous lava of 1737, which contains augite, leucite, and crystals of felspar, he found very regular prisms in a quarry near Torre del Greco; an observation confirmed by modern authorities.‡

Effects of decomposition on lavas.—The decomposition of some of the felspathic lavas, either by simple weathering, or by gaseous emanations, converts them from a hard to a soft clayey state, so that they no longer retain the smallest resemblance to rocks cooled

* Journ. Sci. of vol. xv. p. 177.

† Voy. dans la Campanie, tome i. p. 201.

‡ Mr. Forbes, Edin. Journ. of Sci., No. xviii., Oct. 1828.

down from a state of fusion. The exhalations of sulphuretted hydrogen and muriatic acid, which are disengaged continually from the Solfatara, also produce curious changes on the trachyte of that nearly extinct volcano : the rock is bleached, and becomes porous, fissile, and honeycombed, till at length it crumbles into a white siliceous powder.* Numerous globular concretions, composed of concentric laminæ, are also formed by the same vapours in this decomposed rock.†

Vesuvian minerals. — A great variety of minerals are found in the lavas of Vesuvius and Somma : augite, leucite, felspar, mica, olivine, and sulphur, are most abundant. It is an extraordinary fact, that, in an area of three square miles round Vesuvius, a greater number of simple minerals have been found than in any spot of the same dimensions on the surface of the globe. Häuy enumerated only 380 species of simple minerals as known to him ; and no less than eighty-two had been found on Vesuvius and in the tuffs on the flanks of Somma before the end of the year 1828.‡ Many of these are peculiar to that locality. Some mineralogists have conjectured that the greater part of these were not of Vesuvian origin, but thrown up in fragments from some older formation, through which the gaseous explosions burst. But none of the older rocks in Italy, or elsewhere, contain such an assemblage of mineral products ; and the hypothesis seems to have been prompted by a disinclination to admit that, in times so recent in the earth's history, the laboratory of Nature could have been so prolific in the creation

* Daubeny on Volcanos, p. 169.

† Scrope, Geol. Trans., second series, vol. ii. p. 346.

‡ Monticelli and Covelli, Prodom. della Mineral. Vesuv.

of new and rare compounds. Had Vesuvius been a volcano of high antiquity, formed when Nature

Wanton'd as in her prime, and played at will
Her virgin fancies,

it would have been readily admitted that these, or a much greater variety of substances, had been sublimed in the crevices of lava, just as several new earthy and metallic compounds are known to have been produced by fumeroles, since the eruption of 1822.

Mass enveloping Herculaneum and Pompeii.—In addition to the ejections which fall on the cone, and that much greater mass which finds its way gradually to the neighbouring sea, there is a third portion, often of no inconsiderable thickness, composed of alluviums, spread over the valleys and plains at small distances from the volcano. Aqueous vapours are evolved copiously from volcanic craters during eruptions, and often for a long time subsequently to the discharge of scoriæ and lava: these vapours are condensed in the cold atmosphere surrounding the high volcanic peak, and heavy rains are thus caused. The floods thus occasioned sweep along the impalpable dust and light scoriæ, till a current of mud is produced, which is called, in Campania, “lava d’acqua,” and is often more dreaded than an igneous stream (*lava di fuoco*), from the greater velocity with which it moves. So late as the 27th of October, 1822, one of these alluviums descended the cone of Vesuvius, and, after overspreading much cultivated soil, flowed suddenly into the villages of St. Sebastian and Massa, where, filling the streets and interior of some of the houses, it suffocated seven persons. It will therefore happen very frequently that,

towards the base of a volcanic cone, alternations will be found of lava, alluvium, and showers of ashes.

To which of these two latter divisions the mass enveloping Herculaneum and Pompeii should be referred, has been a question of the keenest controversy ; but the discussion might have been shortened, if the combatants had reflected that, whether volcanic sand and ashes were conveyed to the towns by running water, or through the air, during an eruption, the interior of buildings, so long as the roofs remain entire, together with all underground vaults and cellars, could be filled only by an *alluvium*. We learn from history, that a heavy shower of sand, pumice, and lapilli, sufficiently great to render Pompeii and Herculaneum uninhabitable, fell for eight successive days and nights in the year 79, accompanied by violent rains. We ought, therefore, to find a very close resemblance between the strata covering these towns, and those composing the minor cones of the Phlegræan Fields, accumulated rapidly, like Monte Nuovo, during a continued shower of ejected matter ; with this difference, however, that the strata incumbent on the cities would be horizontal, whereas those in the cones are highly inclined ; and that large angular fragments of rock, which are thrown out near the vent, would be wanting at a distance where small lapilli only can be found. Accordingly, with these exceptions, no identity can be more perfect than the form and distribution of the matter at the base of Monte Nuovo, as laid open by the encroaching sea, and the appearance of the beds superimposed on Pompeii. That city is covered with numerous alternations of different horizontal beds of tuff and lapilli, for the most part thin, and subdivided into very fine layers. I observed the

following section near the amphitheatre, in November, 1828 — (descending series) : —

	Feet. Inches.
1. Black sparkling sand from the eruption of 1822, containing minute regularly formed crystals of augite and tourmaline, from	2 to 3*
2. Vegetable mould	3 0
3. Brown incoherent tuff, full of <i>pisolitic globules</i> in layers, from half an inch to three inches in thickness	1 6
4. Small scoriae and white lapilli	0 3
5. Brown earthy tuff, with numerous pisolitic globules	0 9
6. Brown earthy tuff, with lapilli divided into layers	4 0
7. Layer of whitish lapilli	0 1
8. Grey solid tuff	0 3
9. Pumice and white lapilli	0 3
	<hr/>
	10 4
	<hr/>

Many of the ashes in these beds are vitrified, and harsh to the touch. Crystals of leucite, both fresh and farinaceous, have been found intermixed.† The depth of the bed of ashes above the houses is variable,

* The great eruption, in 1822, caused a covering only a few inches thick on Pompeii. Several feet are mentioned by Mr. Forbes. — Ed. Journ. of Science, No. xix. p. 131. Jan. 1829. But he must have measured in spots where it had drifted. The dust and ashes were five feet thick at the top of the crater, and decreased gradually to ten inches at Torre del Annunziata. The size and weight of the ejected fragments diminished very regularly in the same continuous stratum, as the distance from the centre of projection was greater.

† Forbes, ibid. p. 130.

but seldom exceeds twelve or fourteen feet, and it is said that the higher part of the amphitheatre always projected above the surface; though if this were the case, it seems inexplicable that the city should never have been discovered till the year 1750. It will be observed in the above section, that two of the brown, half-consolidated tuffs are filled with small pisolithic globules. This circumstance is not alluded to in the animated controversy which the Royal Academy of Naples maintained with one of their members, Signor Lippi, as to the origin of the strata incumbent on Pompeii. The mode of aggregation of these globules has been fully explained by Mr. Scrope, who saw them formed in great numbers, in 1822, by rain falling during the eruption on fine volcanic sand, and sometimes, also, produced like hail in the air, by the mutual attraction of the minutest particles of fine damp sand. Their occurrence, therefore, agrees remarkably well with the account of heavy rain, and showers of sand and ashes, recorded in history.*

Lippi entitled his work, “*Fù il fuoco o l’acqua che sotterò Pompei ed Ercolano?*” † and he contended that neither were the two cities destroyed in the year 79, nor by a volcanic eruption, but purely by the agency of water charged with transported matter. His letters, wherein he endeavoured to dispense, as far as possible, with igneous agency, even at the foot of the volcano, were dedicated, with great propriety, to Werner, and afford an amusing illustration of the polemic style in which geological writers of that day indulged themselves. His arguments were partly of

* Scrope, Geol. Trans., second series, vol. ii. p. 346.
Napoli, 1816.

an historical nature, derived from the silence of contemporary historians, respecting the fate of the cities which, as we have already stated, is most remarkable, and partly drawn from physical proofs. He pointed out with great clearness the resemblance of the tufaceous matter in the vaults and cellars at Herculaneum and Pompeii to aqueous alluviums, and its distinctness from ejections which had fallen through the air. Nothing, he observed, but moist pasty matter could have received the impression of a woman's breast, which was found in a vault at Pompeii, or have given the cast of a statue discovered in the theatre at Herculaneum. It was objected to him, that the heat of the tuff in Herculaneum and Pompeii was proved by the carbonization of the timber, corn, papyrus-rolls, and other vegetable substances there discovered: but Lippi replied with truth, that the papyri would have been burnt up, if they had come in contact with fire, and that their being only carbonized was a clear demonstration of their having been enveloped, like fossil wood, in a sediment deposited from water. The Academicians, in their report on his pamphlet, assert, that when the amphitheatre was first cleared out, the matter was arranged on the steps, in a succession of concave layers, accommodating themselves to the interior form of the building, just as snow would lie if it had fallen there. This observation is highly interesting, and points to the difference between the stratification of ashes in an open building, and of mud derived from the same in the interior of edifices and cellars. Nor ought we to call the allegation in question, because it could not be substantiated at the time of the controversy, after the matter had been all removed; although Lippi took advantage of this removal,

and met the argument of his antagonists by requiring them to prove the fact.

Pompeii not destroyed by lava. — There is decisive evidence that no stream of lava has ever reached Pompeii since it was first built, although the foundations of the town stand upon the old leucitic lava of Somma; several streams of which, with tuff interposed, have been cut through in excavations. At Herculaneum the case is different, although the substance which fills the interior of the houses and the vaults must have been introduced in a state of mud, like that found in similar situations in Pompeii; yet the superincumbent mass differs wholly in composition and thickness. Herculaneum was situated several miles nearer to the volcano, and has, therefore, been always more exposed to be covered, not only by showers of ashes, but by alluviums and streams of lava. Accordingly, masses of both have accumulated on each other above the city, to a depth of nowhere less than 70, and in many places of 112 feet.*

The tuff which envelopes the buildings consists of comminuted volcanic ashes, mixed with pumice. A mask imbedded in this matrix has left a cast, the sharpness of which was compared by Hamilton to those in plaster of Paris; nor was the mask in the least degree scorched, as if it had been imbedded in heated matter. This tuff is porous; and, when first excavated, is soft and easily worked, but acquires a considerable degree of induration on exposure to the air. Above this lowest stratum is placed, according to Hamilton, "the matter of six eruptions," each separated from the other by veins of good soil. In these

* Hamilton, *Observ. on Mount Vesuvius*, p. 94. London, 1774.

soils Lippi states that he collected a considerable number of land shells — an observation which is no doubt correct; for many snails burrow in soft soils, and some Italian species descend, when they hibernate, to the depth of five feet and more from the surface. Della Torre also informs us that there is in one part of this superimposed mass a bed of true siliceous lava (*lava di pietra dura*) ; and, as no such current is believed to have flowed till near one thousand years after the destruction of Herculaneum, we must conclude, that the origin of a large part of the covering of Herculaneum was long subsequent to the first inhumation of the place. That city, as well as Pompeii, was a seaport. Herculaneum is still very near the shore, but a tract of land, a mile in length, intervenes between the borders of the Bay of Naples and Pompeii. In both cases the gain of land is due to the filling up of the bed of the sea with volcanic matter, and not to elevation by earthquakes, for there has been no change in the relative level of land and sea. Pompeii stood on a slight eminence composed of the lavas of the ancient Vesuvius, and flights of steps led down to the water's edge. The lowermost of these steps are said to be still on an exact level with the sea.

Condition and contents of the buried cities. — After these observations on the nature of the strata enveloping and surrounding the cities, we may proceed to consider their internal condition and contents, so far at least as they offer facts of geological interest. Notwithstanding the much greater depth at which Herculaneum was buried, it was discovered before Pompeii, by the accidental circumstance of a well being sunk, in 1713, which came right down upon the theatre, where the statues of Hercules and Cleopatra were soon

found. Whether this city or Pompeii, both of them founded by Greek colonies, was the most considerable, is not yet determined; but both are mentioned by ancient authors as among the seven most flourishing cities in Campania. The walls of Pompeii were three miles in circumference; but we have, as yet, no certain knowledge of the dimensions of Herculaneum. In the latter place the theatre alone is open for inspection; the Forum, Temple of Jupiter, and other buildings, having been filled up with rubbish as the workmen proceeded, owing to the difficulty of removing it from so great a depth below ground. Even the theatre is only seen by torchlight, and the most interesting information, perhaps, which the geologist obtains there, is the continual formation of stalactite in the galleries cut through the tuff; for there is a constant percolation of water charged with carbonate of lime mixed with a small portion of magnesia. Such mineral waters must, in the course of time, create great changes in many rocks; especially in lavas, the pores of which they may fill with calcareous spar, so as to convert them into amygdaloids. Some geologists, therefore, are unreasonable when they expect that volcanic rocks of remote eras should accord precisely with those of modern date; since it is obvious that many of those produced in our own time will not long retain the same aspect and internal composition.

Both at Herculaneum and Pompeii, temples have been found with inscriptions commemorating the rebuilding of the edifices after they had been thrown down by an earthquake.* This earthquake happened in the reign of Nero, sixteen years before the cities

* Swinburne and Lalande. Paderni, Phil. Trans. 1758, vol. l. p. 619.

were overwhelmed. In Pompeii, one fourth of which is now laid open to the day, both the public and private buildings bear testimony to the catastrophe. The walls are rent, and in many places traversed by fissures still open. Columns are lying on the ground only half hewn from huge blocks of travertin, and the temple for which they were designed is seen half repaired. In some few places the pavement had sunk in, but in general it was undisturbed, consisting of large irregular flags of lava joined neatly together, in which the carriage wheels have often worn ruts an inch and a half deep. In the wider streets, the ruts are numerous and irregular; in the narrower, there are only two, one on each side, which are very conspicuous. It is impossible not to look with some interest even on these ruts, which were worn by chariot wheels more than seventeen centuries ago; and, independently of their antiquity, it is remarkable to see such deep incisions so continuous in a stone of great hardness.

Small number of skeletons.—A very small number of skeletons have been discovered in either city; and it is clear that most of the inhabitants not only found time to escape, but also to carry with them the principal part of their valuable effects. In the barracks at Pompeii were the skeletons of two soldiers chained to the stocks, and in the vaults of a country-house in the suburbs were the skeletons of seventeen persons, who appear to have fled there to escape from the shower of ashes. They were found inclosed in an indurated tuff, and in this matrix was preserved a perfect cast of a woman, perhaps the mistress of the house, with an infant in her arms. Although her form was imprinted on the rock, nothing but the bones remained. To these a chain of gold was suspended, and on the fingers

of the skeleton were rings with jewels. Against the sides of the same vault was ranged a long line of earthen amphoræ.

The writings scribbled by the soldiers on the walls of their barracks, and the names of the owners of each house written over the doors, are still perfectly legible. The colours of fresco paintings on the stuccoed walls in the interior of buildings are almost as vivid as if they were just finished. There are public fountains decorated with shells laid out in patterns in the same fashion as those now seen in the town of Naples; and in the room of a painter, who was perhaps a naturalist, a large collection of shells was found, comprising a great variety of Mediterranean species, in as good a state of preservation as if they had remained for the same number of years in a museum. A comparison of these remains with those found so generally in a fossil state would not assist us in obtaining the least insight into the time required to produce a certain degree of decomposition or mineralization; for, although under favourable circumstances, much greater alteration might doubtless have been brought about in a shorter period, yet the example before us shows that an inhumation of seventeen centuries may sometimes effect nothing towards the reduction of shells to the state in which fossils are usually found.

The wooden beams in the houses at Herculaneum are black on the exterior, but when cleft open, they appear to be almost in the state of ordinary wood, and the progress made by the whole mass towards the state of lignite is scarcely appreciable. Some animal and vegetable substances of more perishable kinds have of course suffered much change and decay, yet the state of conservation of these is truly remarkable.

Fishing-nets are very abundant in both cities, often quite entire ; and their number at Pompeii is the more interesting from the sea being now, as we stated, a mile distant. Linen has been found at Herculaneum, with the texture well defined ; and in a fruiterer's shop in that city were discovered vessels full of almonds, chestnuts, walnuts, and fruit of the "carubiere," all distinctly recognizable from their shape. A loaf, also, still retaining its form, was found in a baker's shop, with his name stamped upon it. On the counter of an apothecary was a box of pills converted into a fine earthy substance ; and by the side of it a small cylindrical roll, evidently prepared to be cut into pills. By the side of these was a jar containing medicinal herbs. In 1827, moist olives were found in a square glass case, and "caviare," or roe of a fish, in a state of wonderful preservation. An examination of these curious condiments has been published by Covelli, of Naples, and they are preserved hermetically sealed in the museum there.*

Papyri.—There is a marked difference in the condition and appearance of the animal and vegetable substances found in Pompeii and Herculaneum ; those of Pompeii being penetrated by a grey pulverulent tuff, those in Herculaneum seeming to have been first enveloped by a paste which consolidated round them, and then allowed them to become slowly carbonized. Some of the rolls of papyrus at Pompeii still retain their form ; but the writing, and indeed almost all the vegetable matter, appear to have vanished, and to have been replaced by volcanic tuff somewhat pulverulent. At Herculaneum the earthy matter has scarcely ever penetrated ; and the vegetable substance of the papy-

* Mr. Forbes, Edin. Journ. of Sci., No. xix. p. 190., Jan. 1829.

rus has become a thin friable black matter, almost resembling in appearance the tinder which remains when stiff paper has been burnt, in which the letters may still be sometimes traced. The small bundles of papyri, composed of five or six rolls tied up together, had sometimes lain horizontally, and were pressed in that direction, but sometimes they had been placed in a vertical position. Small tickets were attached to each bundle, on which the title of the work was inscribed. In one case only have the sheets been found with writing on both sides of the pages. So numerous are the obliterations and corrections, that many must have been original manuscripts. The variety of handwritings is quite extraordinary : nearly all are written in Greek, but there are a few in Latin. They were almost all found in a suburban villa in the library of one private individual ; and the titles of four hundred of those least injured, which have been read, are found to be unimportant works, but all entirely new, chiefly relating to music, rhetoric, and cookery. There are two volumes of Epicurus "On Nature," and the others are mostly by writers of the same school, only one fragment having been discovered, by an opponent of the Epicurean system, Chrysippus.*

Probability of future discoveries of MSS. — In the opinion of some antiquaries, not one hundredth part of the city has yet been explored ; and the quarters hitherto cleared out, at a great expense, are those where there was the least probability of discovering

* In one of the manuscripts which was in the hands of the interpreters when I visited the museum, the author indulges in the speculation that all the Homeric personages were allegorical — that Agamemnon was the ether, Achilles the sun, Helen the earth, Paris the air, Hector the moon, &c.

manuscripts. As Italy could already boast her splendid Roman amphitheatres and Greek temples, it was a matter of secondary interest to add to their number those in the dark and dripping galleries of Herculaneum; and having so many of the masterpieces of ancient art, we could have dispensed with the inferior busts and statues which could alone have been expected to reward our researches in the ruins of a provincial town. But from the moment that it was ascertained that rolls of papyrus preserved in this city could still be deciphered, every exertion ought to have been steadily and exclusively directed towards the discovery of other libraries. Private dwellings should have been searched, before so much labour and expense were consumed in examining public edifices. A small portion of that zeal and enlightened spirit which prompted the late French and Tuscan expedition to Egypt might long ere this, in a country nearer home, have snatched from oblivion some of the lost works of the Augustan age, or of eminent Greek historians and philosophers. A single roll of papyrus might have disclosed more matter of intense interest than all that was ever written in hieroglyphics.*

Stabiae. — Besides the cities already mentioned, *Stabiae*, a small town about six miles from Vesuvius,

* During my stay at Naples, in 1828, the Neapolitan government, after having discontinued operations for many years, cleared out a small portion of Herculaneum, near the sea, where the covering was least thick. After this expense had been incurred, it was discovered that the whole of the ground had been previously examined, near a century before, by the French Prince d'Elboeuf, who had removed every thing of value! Such is the want of system with which operations have always been, and still are, carried on here, that we may expect similar blunders to be made continually.

and near the site of the modern Castel-a-Mare (see map of volcanic district of Naples), was overwhelmed during the eruption of 79. Pliny mentions that, when his uncle was there, he was obliged to make his escape, so great was the quantity of falling stones and ashes. In the ruins of this place, a few skeletons have been found buried in volcanic ejections, together with some antiquities of no great value, and rolls of papyrus, which like those of Pompeii, were illegible.

Torre del Greco overflowed by lava. — Of the towns hitherto mentioned, Herculaneum alone has been overflowed by a stream of melted matter ; but this did not, as we have seen, enter or injure the buildings, which were previously enveloped or covered over with tuff. But burning torrents have often taken their course through the streets of Torre del Greco, and consumed or inclosed a large portion of the town in solid rock. It seems probable that the destruction of three thousand of its inhabitants, in 1631, which some accounts attribute to boiling water, was principally due to one of those alluvial floods which we before mentioned : but, in 1737, the lava itself flowed through the eastern side of the town, and afterwards reached the sea ; and, in 1794, another current, rolling over the western side, filled the streets and houses, and killed more than four hundred persons. The main street is now quarried through this lava, which supplied building stones for new houses erected where others had been annihilated. The church was half buried in a rocky mass, but the upper portion served as the foundation of a new edifice.

The number of the population at present is estimated at fifteen thousand ; and a satisfactory answer may readily be returned to those who inquire how the in-

habitants can be so “inattentive to the voice of time and the warnings of nature*,” as to rebuild their dwellings on a spot so often devastated. No neighbouring site unoccupied by a town, or which would not be equally insecure, combines the same advantages of proximity to the capital, to the sea, and to the rich lands on the flanks of Vesuvius. If the present population were exiled, they would immediately be replaced by another, for the same reason that the Maremma of Tuscany and the Campagna di Roma will never be depopulated, although the malaria fever commits more havoc in a few years than the Vesuvian lavas in as many centuries. The district around Naples supplies one amongst innumerable examples, that those regions where the surface is most frequently renewed, and where the renovation is accompanied, at different intervals of time, by partial destruction of animal and vegetable life, may nevertheless be amongst the most habitable and delightful on our globe.

I have already made a similar remark when speaking of tracts where aqueous causes are now most active; and the observation applies as well to parts of the surface which are the abode of aquatic animals, as to those which support terrestrial species. The sloping sides of Vesuvius give nourishment to a vigorous and healthy population of about eighty thousand souls; and the surrounding hills and plains, together with several of the adjoining isles, owe the fertility of their soil to matter ejected by prior eruptions. Had the fundamental limestone of the Apennines remained uncovered throughout the whole area, the country could not have sustained a twentieth part of its present inhabitants. This will be apparent to every geo-

* Sir H. Davy, *Consolations in Travel*, p. 66.

logist who has marked the change in the agricultural character of the soil the moment he has passed the utmost boundary of the volcanic ejections, as when, for example, at the distance of about seven miles from Vesuvius, he leaves the plain and ascends the declivity of the Sorrentine Hills.

Concluding remarks.— Yet, favoured as this region has been by Nature from time immemorial, the signs of the changes imprinted on it during the period that it has served as the habitation of man may appear in after-ages to indicate a series of unparalleled disasters. Let us suppose that at some future time the Mediterranean should form a gulf of the great ocean, and that the waves and tidal current should encroach on the shores of Campania, as it now advances upon the eastern coast of England; the geologist will then behold the towns already buried, and many more which will evidently be entombed hereafter, laid open in the steep cliffs, where he will discover buildings superimposed above each other, with thick intervening strata of tuff or lava — some unscathed by fire, like those of Herculaneum and Pompeii; others half melted down, as in Torre del Greco; and many shattered and thrown about in strange confusion, as in Tripereola, beneath Monte Nuovo. Among the ruins will be seen skeletons of men, and impressions of the human form stamped in solid rocks of tuff. Nor will the signs of earthquakes be wanting. The pavement of part of the Domitian Way, and the Temple of the Nymphs, submerged at high tide, will be uncovered at low water, the columns remaining erect and uninjured. Other temples which had once sunk down, like that of Serapis, will be found to have been upraised again by subsequent movements. If they who study these

phenomena, and speculate on their causes, assume that there were periods when the laws of Nature or the whole course of natural events differed greatly from those observed in their own time, they will scarcely hesitate to refer the wonderful monuments in question to those primeval ages. When they consider the numerous proofs of reiterated catastrophes to which the region was subject, they may, perhaps, commiserate the unhappy fate of beings condemned to inhabit a planet during its nascent and chaotic state, and feel grateful that their favoured race has escaped such scenes of anarchy and misrule.

Yet what was the real condition of Campania during those years of dire convulsion? “A climate where heaven’s breath smells sweet and wooingly — a vigorous and luxuriant nature unparalleled in its productions — a coast which was once the fairy land of poets, and the favourite retreat of great men. Even the tyrants of the creation loved this alluring region, spared it, adorned it, lived in it, died in it.”* The inhabitants, indeed, have enjoyed no immunity from the calamities which are the lot of mankind; but the principal evils which they have suffered must be attributed to moral, not to physical, causes — to disastrous events over which man might have exercised a control, rather than to the inevitable catastrophes which result from subterranean agency. When Spartacus encamped his army of ten thousand gladiators in the old extinct crater of Vesuvius, the volcano was more justly a subject of terror to Campania, than it has ever been since the rekindling of its fires.

* Forsyth’s Italy, vol. ii.

CHAPTER XIII.

ETNA.

External physiognomy of Etna — Lateral cones — Their successive obliteration — Early eruptions — Monti Rossi in 1669 — Towns overflowed by lava — Part of Catania overflowed — Mode of advance of a current of lava — Subterranean caverns — Marine strata at base of Etna — Val del Bove not an ancient crater — Its scenery — Form, composition, and origin of the dikes — Linear direction of cones formed in 1811 and 1819 — Lavas and breccias — Flood produced by the melting of snow by lava — Glacier covered by a lava stream — Val del Bove how formed — Structure and origin of the cone of Etna — Whether the inclined sheets of lava were originally horizontal — Antiquity of Etna — Whether signs of diluvial waves are observable on Etna.

External physiognomy of Etna. — AFTER Vesuvius, our most authentic records relate to Etna, which rises near the sea in solitary grandeur to the height of nearly eleven thousand feet.* The base of the cone is almost circular, and eighty-seven English miles in circumfer-

* In 1815, Captain Smyth ascertained, trigonometrically, that the height of Etna was 10,874 feet. The Catanians, disappointed that their mountain had lost nearly 2000 feet of the height assigned to it by Recupero, refused to acquiesce in the decision. Afterwards, in 1824, Sir J. Herschel, not being aware of Captain Smyth's conclusions, determined by careful barometrical measurement, that the height was 10,872½ feet. This singular agreement of results so differently obtained was spoken of by Herschel as "a happy accident;" but Dr. Wollaston remarked that "it was one of those accidents which would not have happened to two fools."

ence; but if we include the whole district over which its lavas extend, the circuit is probably twice that extent.

Divided into three regions. — The cone is divided by nature into three distinct zones, called the *fertile*, the *woody*, and the *desert* regions. The first of these, comprising the delightful country around the skirts of the mountain, is well cultivated, thickly inhabited, and covered with olives, vines, corn, fruit-trees, and aromatic herbs. Higher up, the woody region encircles the mountain — an extensive forest, six or seven miles in width, affording pasturage for numerous flocks. The trees are of various species, the chestnut, oak, and pine being most luxuriant; while in some tracts are groves of cork and beech. Above the forest is the desert region, a waste of black lava and scoriae; where, on a kind of plain, rises the cone to the height of about eleven hundred feet, from which sulphureous vapours are continually evolved. The most grand and original feature in the physiognomy of Etna is the multitude of minor cones which are distributed over its flanks, and which are most abundant in the woody region. These, although they appear but trifling irregularities when viewed from a distance as subordinate parts of so imposing and colossal a mountain, would, nevertheless, be deemed hills of considerable altitude in almost any other region.

Cones produced by lateral eruptions. — Without enumerating numerous monticules of ashes thrown out at different points, there are about eighty of these secondary volcanos, of considerable dimensions; fifty-two on the west and north, and twenty-seven on the east side of Etna. One of the largest, called Monte Minardo, near Bronte, is upwards of 700 feet in height,

and a double hill near Nicolosi, called Monti Rossi, formed in 1669, is 450 feet high, and the base two miles in circumference ; so that it somewhat exceeds in size Monte Nuovo, before described. Yet it ranks only as a cone of the second magnitude amongst those produced by the lateral eruptions of Etna. On looking down from the lower borders of the desert region, these volcanos present us with one of the most delightful and characteristic scenes in Europe. They afford every variety of height and size, and are arranged in beautiful and picturesque groups. However uniform they may appear when seen from the sea, or the plains below, nothing can be more diversified than their shape when we look from above into their craters, one side of which is generally broken down. There are, indeed, few objects in nature more picturesque than a wooded volcanic crater. The cones situated in the higher parts of the forest zone are chiefly clothed with lofty pines ; while those at a lower elevation are adorned with chestnuts, oaks, beech, and holm.

Successive obliteration of these cones.—The history of the eruptions of Etna, imperfect and interrupted as it is, affords us, nevertheless, much insight into the manner in which the whole mountain has successively attained its present magnitude and internal structure. The principal cone has more than once fallen in and been reproduced. In 1444 it was 320 feet high, and fell in after the earthquakes of 1537. In the year 1693, when a violent earthquake shook the whole of Sicily, and killed sixty thousand persons, the cone lost so much of its height, says Boccone, that it could not be seen from several places in Valdemone, from which it was before visible. The greater number of eruptions happen either from the great crater, or from lateral

openings in the desert region. When hills are thrown up in the middle zone, and project beyond the general level, they gradually lose their height during subsequent eruptions; for when lava runs down from the upper parts of the mountain, and encounters any of these hills, the stream is divided, and flows round them so as to elevate the gently sloping grounds from which they rise. In this manner a deduction is often made at once of twenty or thirty feet, or even more, from their height. Thus, one of the minor cones, called Monte Peluso, was diminished in altitude by a great lava stream which encircled it in 1444; and another current has recently taken the same course — yet this hill still remains four or five hundred feet high.

There is a cone called Monte Nucilla, near Nicolosi, round the base of which several successive currents have flowed, and showers of ashes have fallen, since the time of history, till at last, during an eruption in 1536, the surrounding plain was so raised, that the top of the cone alone was left projecting above the general level. Monte Nero, situated above the Grotta dell' Capre, was in 1766 almost submerged by a current; and Monte Capreolo afforded, in the year 1669, a curious example of one of the last stages of obliteration: for a lava stream, descending on a high ridge which had been built up by the continued superposition of successive lavas, flowed directly into the crater, and nearly filled it. The lava, therefore, of each new lateral cone tends to detract from the relative height of lower cones above their base: so that the flanks of Etna, sloping with a gentle inclination, envelop in succession a great multitude of minor volcanos, while new ones spring up from time to time.

Early eruptions of Etna.—Etna appears to have been in activity from the earliest times of tradition; for Diodorus Siculus mentions an eruption which caused a district to be deserted by the Sicani before the Trojan war. Thucydides informs us, that in the sixth year of the Peloponnesian war, or in the spring of the year 425 b. c., a lava stream ravaged the environs of Catania, and this, he says, was the third eruption which had happened in Sicily since the colonization of that island by the Greeks.* The second of the three eruptions alluded to by the historian took place in the year 475 b. c., and was that so poetically described by Pindar, two years afterwards, in his first Pythian ode:—

κιῶν
Δ' οὐρανία συνεχεῖ
Νιφεσσός Αἰτνα, πανετεῖ
Χιονος οξεῖας τιθῆνα·

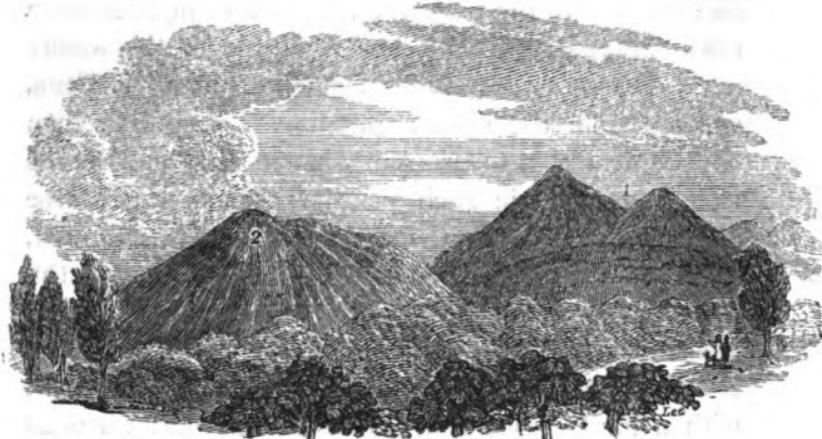
In these and the seven verses which follow, a graphic description is given of Etna, such as it appeared five centuries before the Christian era, and such as it has been seen when in eruption in modern times. The poet is only making a passing allusion to the Sicilian volcano, as the mountain under which Typhœus lay buried, yet by a few touches of his master hand every striking feature of the scene has been faithfully pourtrayed. We are told of “the snowy Etna, the pillar of heaven,—the nurse of everlasting frost, in whose deep caverns lie concealed the fountains of unapproachable fire—a stream of eddying smoke by day—a bright and ruddy flame by night; and burning rocks rolled down with loud uproar into the sea.”

* Book iii., at the end.

Eruption of 1669 — Monti Rossi formed.—The great eruption which happened in the year 1669 is the first which claims particular attention. An earthquake had levelled to the ground all the houses in Nicolosi, a town situated near the lower margin of the woody region, about twenty miles from the summit of Etna, and ten from the sea at Catania. Two gulphs then opened near that town, from whence sand and scoriæ were thrown up in such quantity, that, in the course of three or four months, a double cone was formed, called Monti Rossi, about 450 feet high. But the most extraordinary phenomenon occurred at the commencement of the convulsion in the plain of S. Lio. A fissure six feet broad, and of unknown depth, opened with a loud crash, and ran in a somewhat tortuous course to within a mile of the summit of Etna. Its direction was from north to south, and its length twelve miles. It emitted a most vivid light. Five other parallel fissures of considerable length afterwards opened one after the other, and emitted smoke, and gave out bellowing sounds which were heard at the distance of forty miles. This case seems to present the geologist with an illustration of the manner in which those continuous dikes of vertical porphyry were formed, which are seen to traverse some of the older lavas of Etna; for the light emitted from the great rent of S. Lio appears to indicate that the fissure was filled to a certain height with incandescent lava, probably to the height of an orifice not far distant from Monti Rossi, which at that time opened and poured out a lava current. When the melted matter in such a rent has cooled, it must become a solid wall or dike, intersecting the older rocks of which the mountain is composed; similar rents have been observed during subsequent

eruptions, as in 1832, when they ran in all directions from the centre of the volcano. It has been justly

Fig. 32.

*Minor cones on the flanks of Etna.*

- 1, Monti Rossi, near Nicolosi, formed in 1669.
2, Vampeluso ? *

remarked by M. Elie de Beaumont, that such star-shaped fractures may indicate a slight upheaval of the whole of Etna. They may be the signs of the stretching of the mass, which may thus be raised gradually by a force from below.†

The lava current of 1669, before alluded to, soon reached in its course a minor cone called Mompiliere, at the base of which it entered a subterranean grotto, communicating with a suite of those caverns which are so common in the lavas of Etna. Here it appears

* The hill which I have here introduced was called by my guide Vampolara, but the name given in the text is the nearest to this, which I find in Gemmellaro's Catalogue of Minor Cones.

† *Mém. pour servir, &c., tom. iv. p. 116.*

to have melted down some of the vaulted foundations of the hill, so that the whole of that cone became slightly depressed and traversed by numerous open fissures.

Part of Catania destroyed. — The lava, after overflowing fourteen towns and villages, some having a population of between three and four thousand inhabitants, arrived at length at the walls of Catania. These had been purposely raised to protect the city; but the burning flood accumulated till it rose to the top of the rampart, which was sixty feet in height, and then it fell in a fiery cascade and overwhelmed part of the city. The wall, however, was not thrown down, but was discovered long afterwards, by excavations made in the rock by the Prince of Biscari; so that the traveller may now see the solid lava curling over the top of the rampart as if still in the very act of falling.

This great current had performed a course of fifteen miles before it entered the sea, where it was still six hundred yards broad, and forty feet deep. It covered some territories in the environs of Catania, which had never before been visited by the lavas of Etna. While moving on, its surface was in general a mass of solid rock; and its mode of advancing, as is usual with lava streams, was by the occasional fissuring of the solid walls. A gentleman of Catania, named Pappalardo, desiring to secure the city from the approach of the threatening torrent, went out with a party of fifty men whom he had dressed in skins to protect them from the heat, and armed with iron crows and hooks. They broke open one of the solid walls which flanked the current near Belpasso, and immediately forth issued a rivulet of melted matter which took the direction of Paternò; but the inhabitants of that town, being

alarmed for their safety, took up arms and put a stop to further operations.*

As another illustration of the solidity of the walls of an advancing lava stream, I may mention an adventure related by Recupero, who, in 1766, had ascended a small hill formed of ancient volcanic matter, to behold the slow and gradual approach of a fiery current, two miles and a half broad; when suddenly two small threads of liquid matter issuing from a crevice detached themselves from the main stream, and ran rapidly towards the hill. He and his guide had just time to escape, when they saw the hill, which was fifty feet in height, surrounded, and in a quarter of an hour melted down into the burning mass, so as to flow on with it.

But it must not be supposed that this complete fusion of rocky matter coming in contact with lava is of universal, or even common, occurrence. It probably happens when fresh portions of incandescent matter come successively in contact with fusible materials. In many of the dikes which intersect the tuffs and lavas of Etna, there is scarcely any perceptible alteration effected by heat on the edges of the horizontal beds, in contact with the vertical and more crystalline mass. On the site of Mompiliere, one of the towns overflowed in the great eruption above described, an excavation was made in 1704; and by immense labour the workmen reached, at the depth of thirty-five feet, the gate of the principal church, where there were three statues, held in high veneration. One of these, together with a bell, some money, and other articles, were extracted in a good state of preservation from beneath a great arch formed by the lava. It seems very extraordinary.

* Ferrara, *Descriz. dell' Etna*; p. 108.

that any works of art, not encased with tuff, like those in Herculaneum, should have escaped fusion in hollow spaces left open in this lava current, which was so hot at Catania eight years after it entered the town, that it was impossible to hold the hand in some of the crevices.

Subterranean caverns on Etna.—Mention was made of the entrance of a lava stream into a subterranean grotto, whereby the foundations of a hill were partially undermined. Such underground passages are among the most curious features on Etna, and appear to have been produced by the hardening of the lava, during the escape of great volumes of elastic fluids, which are often discharged for many days in succession, after the crisis of the eruption is over. Near Nicolosi, not far from Monti Rossi, one of these great openings may be seen, called the Fossa della Palomba, 625 feet in circumference at its mouth, and seventy-eight deep. After reaching the bottom of this, we enter another dark cavity, and then others in succession, sometimes descending precipices by means of ladders. At length the vaults terminate in a great gallery ninety feet long, and from fifteen to fifty broad, beyond which there is still a passage, never yet explored; so that the extent of these caverns remains unknown.* The walls and roofs of these great vaults are composed of rough and bristling scoriæ, of the most fantastic forms.

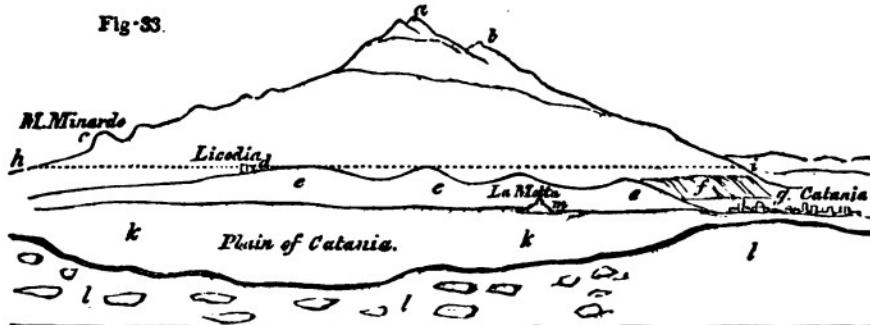
Marine strata at base of Etna.—If we skirt the fertile region at the base of Etna on its southern and eastern sides, we behold marine strata of clay, sand, and volcanic tuff, cropping out from beneath the modern lavas. The marine fossil shells occurring in these strata are all of them, or nearly all, identical

* Ferrara, *Descriz. dell' Etna.* Palermo, 1818.

with species now inhabiting the Mediterranean; and as they appear at the height of from 600 to 800 feet above the sea, near Catania, they clearly prove that there has been in this region, as in other parts of Sicily farther to the south, an upward movement of the ancient bed of the sea. It is fair, therefore, to infer that the whole mountain, with the exception of those parts which are of very modern origin, has participated in this upheaval.

If we view Etna from the south, we see the marine deposits above alluded to forming a low line of hills (*e, e*, fig. 33.) or a steep inland slope or cliff (*f*), as in the annexed drawing taken from the limestone platform of Primosole. It should be observed, however, in reference to this view, that the height of the volcanic cone is ten times greater than the hills at its base (*e, e*), although it appears less elevated, because

Fig. 33.

*View of Etna from the summit of the limestone platform of Primosole.*

- a*, Highest cone.
- b*, Montagnuola.
- c*, Monte Minardo, with smaller lateral cones above.
- d*, Town of Licodia dei Monaci.
- e*, Marine formation called creta, argillaceous and sandy beds with a few shells, and associated volcanic rocks.
- f*, Escarpment of stratified subaqueous volcanic tuff, &c., north-west of Catania.
- g*, Town of Catania.
- h, i*, Dotted line expressing the highest boundary along which the marine strata are occasionally seen.
- k*, Plain of Catania.
- m*, Limestone platform of Primosole of the Newer Pliocene period.
- n*, La Motta di Catania.

the summit of the cone is ten or twelve times more distant from the plain of Catania than is Licodia.

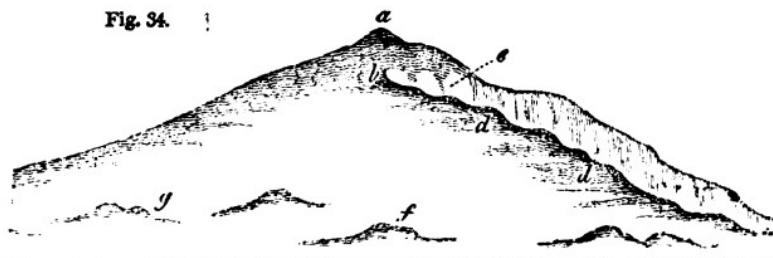
The mountain is in general of a very symmetrical form, a flattened cone broken on its eastern side, by a deep valley called the Val del Bove, or in the provincial dialect of the peasants "Val di Bué," for here the herdsman

— “in reductâ valle *mugientum*
Prospectat errantes greges.”

Dr. Buckland was, I believe, the first English geologist who examined this valley with attention, and I am indebted to him for having described it to me, before I visited Sicily, as more worthy of attention than any single spot in that island, or perhaps in Europe.

The Val del Bove commences near the summit of Etna, and descending into the woody region, is farther

Fig. 34.



Great valley on the east side of Etna.

- | | |
|--|---------------------------|
| a, Highest cone. | b, Montagnuola. |
| c, Head of Val del Bove. | d, d, Serre del Solfizio. |
| e, Village of Zaffarana on the lower border of the woody region. | |
| f, One of the lateral cones. | g, Monti Rossi. |

continued on one side by a second and narrower valley, called the Val di Calanna. Below this another, named the Val di St. Giacomo, begins, — a long narrow ravine, which is prolonged to the neighbourhood of Zaffarana (e. Fig. 34.), on the confines of the fertile region. These natural incisions, into the side of the

volcano, are of such depth that they expose to view a great part of the structure of the entire mass, which, in the Val del Bove, is laid open to the depth of from 3000 to above 4000 feet from the summit of Etna. The geologist thus enjoys an opportunity of ascertaining how far the internal conformation of the cone corresponds with what he might have anticipated as the result of that mode of increase which has been witnessed during the historical era.

Description of Plate VIII. — The accompanying view (Pl. VIII.) is part of a panoramic sketch which I made in November, 1828, and may assist the reader in comprehending some topographical details to be alluded to in the sequel, although it can convey no idea of the picturesque grandeur of the scene.

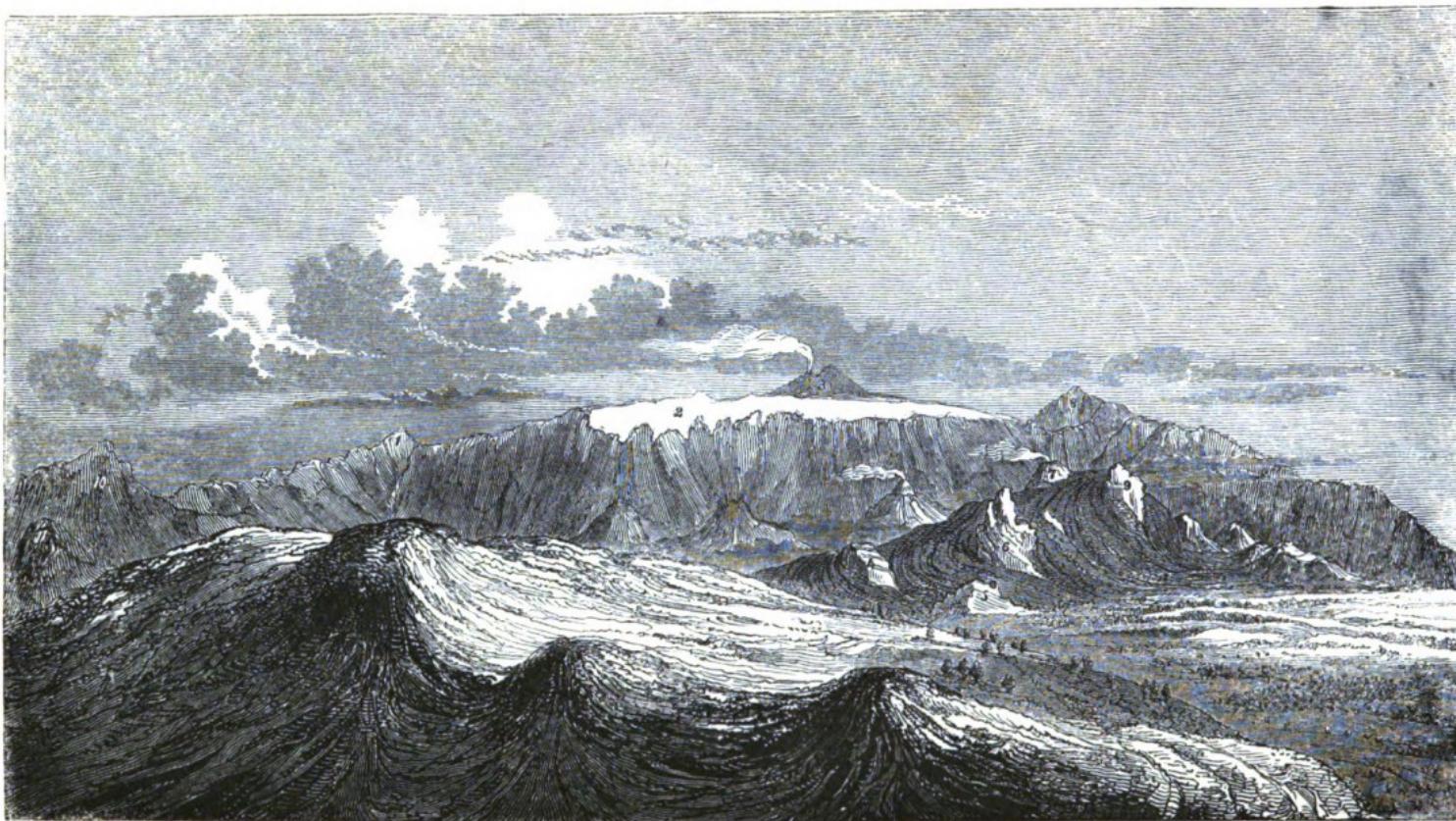
The great lava-currents of 1819 and 1811 are seen pouring down from the higher parts of the valley, overrunning the forests of the great plain, and rising up in the foreground on the left with a rugged surface, on which many hillocks and depressions appear, such as often characterize a lava-current immediately after its consolidation.

The small cone, No. 7., was formed in 1811, and was still smoking when I saw it in 1828. The other small volcano to the left, from which vapour is issuing, was, I believe, one of those formed in 1819.

The following are the names of some of the other points indicated in the sketch :—

- | | | |
|------------------------|--------------------|----------------------|
| 1, Montagnuola. | 5, Finocchio. | 9, Musara. |
| 2, Torre del Filosofo. | 6, Capra. | 10, Zocolaro. |
| 3, Highest cone. | 7, Cone of 1811. | 11, Roccadi Calanna. |
| 4, Lepra. | 8, Cima del Asino. | |

Description of Plate. IX. — The second view (Pl. IX.) represents the same valley as seen from above, or look-



VIEW LOOKING UP THE VAL DEL BOVE, ETNA



VIEW OF VAL DEL BOVE, ETNA, AS SEEN FROM ABOVE, OR FROM CRATER OF 1810.

ing directly down the Val del Bove, from the summit of the principal crater formed in 1819.* I am unable to point out the precise spot which this crater would occupy in the view represented in Plate VIII.; but I conceive that it would appear in the face of the great precipice, near which the smoke issuing from the cone No. 7. is made to terminate. There are many ledges of rock on the face of that precipice where eruptions have occurred.

The circular form of the Val del Bove is well shown in this view. (Pl. IX.) To the right and left are the lofty precipices which form the southern and northern sides of the great valley, and which are intersected by dikes projecting in the manner afterwards to be described. In the distance appears the "fertile region" of Etna, extending like a great plain along the sea coast.

The spots particularly referred to in the plate are the following :—

- a*, Cape Spartivento, in Italy, of which the outline is seen in the distance.
- b*, The promontory of Taormino, on the Sicilian coast.
- c*, The river Alcantra.
- d*, The small village of Riposto.
- f*, The town of Aci Reale.
- g*, Cycloian islands, or "Faraglioni," in the Bay of Trezza.
- h*, The great harbour of Syracuse.
- k*, The Lake of Lentini.
- i*, The city of Catania, near which is marked the course of the lava which flowed from the Monti Rossi in 1669, and destroyed part of the city.
- l*, To the left of the view is the crater of 1811, which is also shown at No. 7., in Plate VIII.
- m*, Rock of Musara, also seen at No. 9., in Plate VIII.
- e*, Valley of Calanna.

* This view is taken from a sketch made by Mr. James Bridges, corrected after comparison with several sketches of my own.

The Val del Bove is of truly magnificent dimensions, a vast amphitheatre four or five miles in diameter, surrounded by nearly vertical precipices, varying from 1000 to above 3000 feet in height, the loftiest being at the upper end, and the height gradually diminishing on both sides. The feature which first strikes the geologist as distinguishing the boundary cliffs of this valley, is the prodigious multitude of vertical dikes, which are seen in all directions traversing the volcanic beds. The circular form of this great chasm, and the occurrence of these countless dikes, amounting perhaps to several thousands in number, so forcibly recalled to my mind the phenomena of the Atrio del Cavallo, on Vesuvius, that I at first imagined that I had entered a vast crater, on a scale as far exceeding that of Somma as Etna surpasses Vesuvius in magnitude.

But I was soon undeceived when I had attentively explored the different sides of the great amphitheatre, in order to satisfy myself whether the semicircular wall of the Val del Bove had ever formed the boundary of a crater, and whether the beds had the same quâ-quâ-versal dip which is so beautifully exhibited in the escarpment of Somma. Had the supposed analogy between Somma and the Val del Bove held true, the tuffs and lavas at the head of the valley would have dipped to the west, those on the north side towards the north, and those on the southern side to the south. But such I did not find to be the inclination of the beds; they all dip towards the sea, or nearly east, as in the valleys of St. Giacomo and Calanna below.

Scenery of the Val del Bove. — Let the reader picture to himself a large amphitheatre, five miles in diameter, and surrounded on three sides by precipices

from to 2000 to 3000 feet in height. If he has beheld that most picturesque scene in the chain of the Pyrenees, the celebrated "cirque of Gavarnie," he may form some conception of the magnificent circle of precipitous rocks which inclose, on three sides, the great plain of the Val del Bove. This plain has been deluged by repeated streams of lava; and although it appears almost level, when viewed from a distance, it is, in fact, more uneven than the surface of the most tempestuous sea. Besides the minor irregularities of the lava, the valley is in one part interrupted by a ridge of rocks, two of which, Musara and Capra, are very prominent. It can hardly be said that they

— “ like giants stand
To sentinel enchanted land ;”

for although, like the Trosachs, in the Highlands of Scotland, they are of gigantic dimensions, and appear almost isolated, as seen from many points, yet the stern and severe grandeur of the scenery which they adorn is not such as would be selected by a poet for a vale of enchantment. The character of the scene would accord far better with Milton's picture of the infernal world; and if we imagine ourselves to behold in motion, in the darkness of the night, one of those fiery currents which have so often traversed the great valley, we may well recall

— “ yon dreary plain, forlorn and wild,
The seat of desolation, void of light,
Save what the glimmering of these livid flames
Casts pale and dreadful.”

The face of the precipices already mentioned is broken in the most picturesque manner by the vertical

walls of lava which traverse them. These masses usually stand out in relief, are exceedingly diversified in form, and of immense altitude. In the autumn, their black outline may often be seen relieved by clouds of fleecy vapour which settle behind them, and do not disperse until mid-day, continuing to fill the valley while the sun is shining on every other part of Sicily, and on the higher regions of Etna.

As soon as the vapours begin to rise, the changes of scene are varied in the highest degree, different rocks being unveiled and hidden by turns, and the summit of Etna often breaking through the clouds for a moment with its dazzling snows, and being then as suddenly withdrawn from the view.

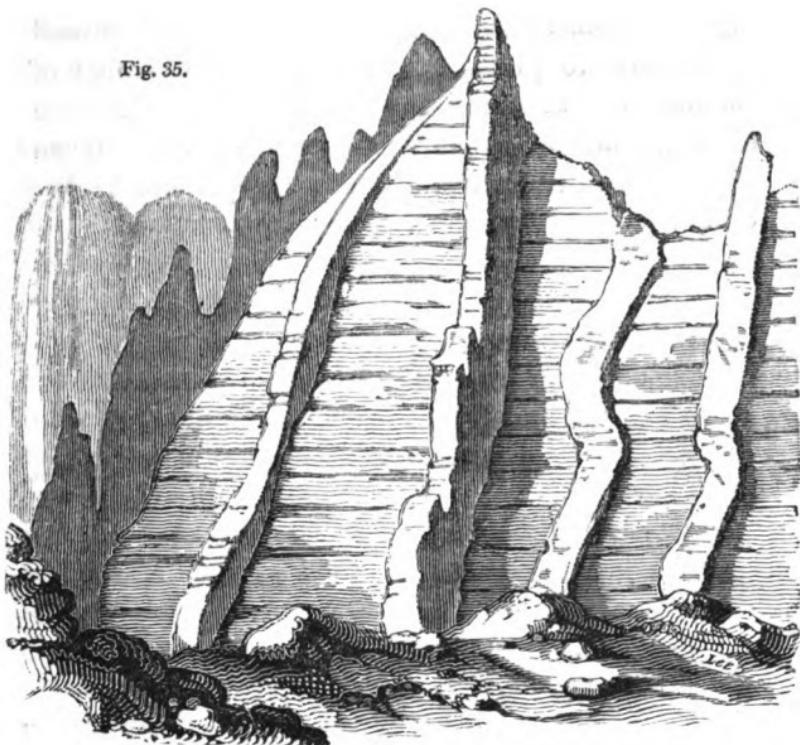
As unusual silence prevails ; for there are no torrents dashing from the rocks, nor any movement of running water in this valley, such as may almost invariably be heard in mountainous regions. Every drop of water that falls from the heavens, or flows from the melting ice and snow, is instantly absorbed by the porous lava ; and such is the dearth of springs, that the herdsman is compelled to supply his flocks, during the hot season, from stores of snow laid up in hollows of the mountain during winter.

The strips of green herbage and forest land, which have here and there escaped the burning lavas, serve, by contrast, to heighten the desolation of the scene. When I visited the valley, nine years after the eruption of 1819, I saw hundreds of trees, or rather the white skeletons of trees, on the borders of the black lava, the trunks and branches being all leafless, and deprived of their bark by the scorching heat emitted from the melted rock ; an image recalling those beautiful lines :—

— “ As when heaven's fire
 Hath scath'd the forest oaks, or mountain pines,
 With singed top their stately growth, though bare,
 Stands on the blasted heath.”

Form, composition, and origin of the dikes. — But without indulging the imagination any longer in descriptions of scenery, I may observe, that the dikes before mentioned form unquestionably the most interesting geological phenomenon in the Val del Bove. Some of these are composed of trachyte, others of

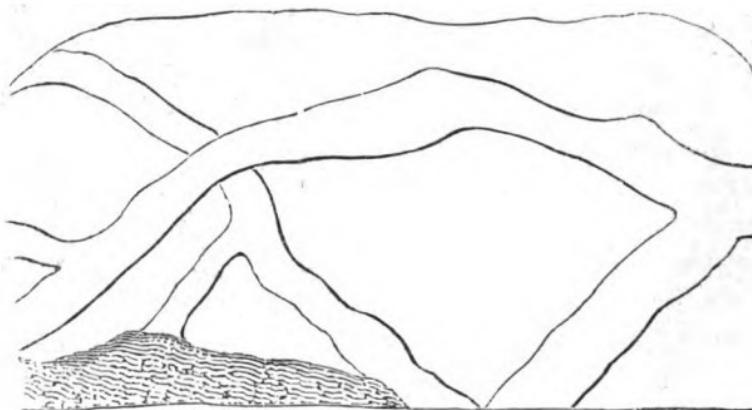
Fig. 35.

*Dikes at the base of the Serre del Solfizio, Etna.*

compact blue basalt with olivine. They vary in breadth from two to twenty feet and upwards, and

usually project from the face of the cliffs, as represented in the annexed drawing (Fig. 35.). They consist of harder materials than the strata which they traverse, and therefore waste away less rapidly under the influence of that repeated congelation and thawing to which the rocks in this zone of Etna are exposed. The dikes are, for the most part, vertical, but sometimes they run in a tortuous course through the tuffs and breccias, as represented in Fig. 36. In the escarpment of Somma, where similar walls of lava cut through alternating beds of sand and scoriæ, a coating of coal-black rock, approaching in its nature and appearance to pitchstone, is seen at the contact of the dike with the intersected beds. I did not observe such parting layers at the junction of the Etnean dikes which I examined, but they may perhaps be discoverable.

Fig. 36.

*Tortuous veins of lava, at Punto di Giumento, Etna.*

The geographical position of these dikes is most interesting, as they are very numerous near the head of the Val del Bove, where the cones of 1811 and 1819

were thrown up, as also in that zone of the mountain where lateral eruptions are frequent; whereas, in the Valley of Calanna, which is below that parallel, and in a region where lateral eruptions are extremely rare, scarcely any dikes are seen, and none whatever still lower in the valley of St. Giacomo. This is precisely what we might have expected, if we consider the vertical fissures now filled with rock to have been the feeders of lateral cones, or, in other words, the channels which gave passage to the lava-currents and scoriæ that have issued from vents in the forest zone. In other parts of Etna there may be numerous dikes at as low a level as the Valley of Calanna, because the line of lateral eruptions is not everywhere at the same height above the sea; but in the section above alluded to there appeared to me an obvious connection between the frequency of dikes and of lateral eruptions.

Some fissures may have been filled from above, but I did not see any which, by terminating downwards, gave proof of such an origin. Almost all the isolated masses in the Val del Bove, such as Capra, Musara, and others, are traversed by dikes, and may, perhaps, have partly owed their preservation to that circumstance, if at least the action of occasional floods has been one of the destroying causes in the Val del Bove; for there is nothing which affords so much protection to a mass of strata against the undermining action of running water as a perpendicular dike of hard rock.

In the accompanying drawing (Fig. 37.) the flowing of the lavas of 1811 and 1819, between the rocks Finochio, Capra, and Musara, is represented. The height of the two last-mentioned isolated masses has been much diminished by the elevation of their base, caused by these currents. They may, perhaps, be the

Fig. 37.

*View of the rocks Finocchio, Capra, and Musara, Val del Bove.*

remnants of lateral cones which existed before the Val del Bove was formed, and may hereafter be once more buried by the lavas that are now accumulating in the valley.

From no point of view are the dikes more conspicuous than from the summit of the highest cone of Etna; a view of some of them is given in the annexed drawing. (Fig. 38.)

Eruption of 1811.—I have alluded to the streams of lava which were poured forth in 1811 and 1819. Gemmellaro, who witnessed these eruptions, informs us that the great crater in 1811 first testified, by its loud detonations, that a column of lava had ascended to near the summit of the mountain. A violent shock was then felt, and a stream broke out from the side of the cone, at no great distance from its apex. Shortly after this had ceased to flow, a second stream burst forth at

Fig. 38.



*View from the summit of Etna into the Val del Bove.**

another opening, considerably below the first; then a third still lower, and so on till seven different issues had been thus successively formed, all lying upon the

* This drawing is part of a panoramic sketch which I made from the summit of the cone, December 1. 1828, when every part of Etna was free from clouds except the Val del Bove. The small cone, and the crater nearest the foreground, were among those formed during the eruptions of 1810 and 1811.

same straight line. It has been supposed that this line was a perpendicular rent in the internal framework of the mountain, which rent was probably not produced at one shock, but prolonged successively downwards, by the lateral pressure and intense heat of the internal column of lava, as it subsided by gradual discharge through each vent.*

Eruption of 1819.—In 1819 three large mouths or caverns opened very near those which were formed in the eruptions of 1811, from which flames, red-hot cinders, and sand, were thrown up with loud explosions. A few minutes afterwards another mouth opened below, from which flames and smoke issued; and finally a fifth, lower still, whence a torrent of lava flowed, which spread itself with great velocity over the deep and broad valley called “Val del Bove.” This stream flowed two miles in the first twenty-four hours, and nearly as far in the succeeding day and night. The three original mouths at length united into one large crater, and sent forth lava, as did the inferior apertures, so that an enormous torrent poured down the “Val del Bove.” When it arrived at a vast and almost perpendicular precipice, at the head of the valley of Calanna, it poured over in a cascade, and, being hardened in its descent, made an inconceivable crash as it was dashed against the bottom. So immense was the column of dust raised by the abrasion of the tufaceous hill over which the hardened mass descended, that the Cataniens were in great alarm, supposing a new eruption to have burst out in the woody region, exceeding in violence that near the summit of Etna.

* Scrope on Volcanos, p. 153.

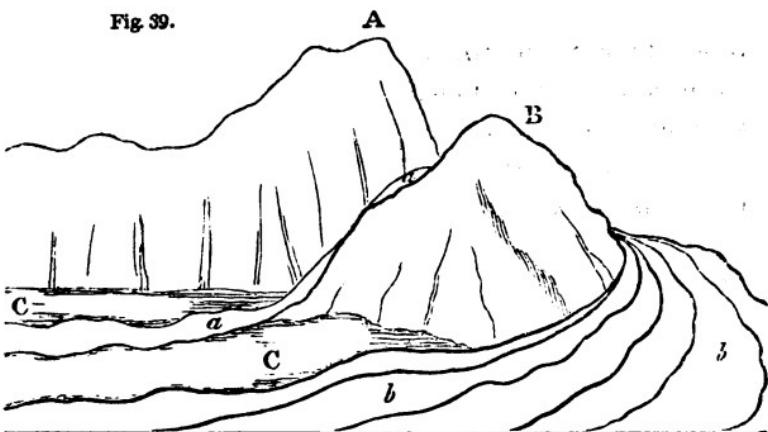
Mode of advance of the lava. — Of the cones thrown up during this eruption, not more than two are of sufficient magnitude to be numbered among those eighty which were before described as adorning the flanks of Etna. The surface of the lava which deluged the "Val del Bove" consists of rocky and *angular blocks*, tossed together in the utmost disorder. Nothing can be more rugged, or more unlike the smooth and even superficies which those who are unacquainted with volcanic countries may have pictured to themselves, in a mass of matter which had consolidated from a liquid state. Mr. Scrope observed this current in the year 1819, slowly advancing down a considerable slope, at the rate of about a yard an hour, nine months after its first emission. The lower stratum being arrested by the resistance of the ground, the upper or central part gradually protruded itself, and being unsupported, fell down. This in its turn was covered by a mass of more liquid lava, which swelled over it from above. The current had all the appearance of a huge heap of rough and large cinders rolling over and over upon itself by the effect of an extremely slow propulsion from behind. The contraction of the crust as it solidified, and the friction of the scoriform cakes against one another, produced a crackling sound. Within the crevices a dull red heat might be seen by night, and vapour issuing in considerable quantity was visible by day.*

It was stated that when the lava of 1819 arrived at the head of the Valley of Calanna, after flowing down the Val del Bove, it descended in a cascade. This stream, in fact, like many previous currents of lava which have flowed down successively from the

* Scrope on Volcanos, p. 102.

higher regions of Etna, was turned by a great promontory projecting from the southern side of the Val del Bove. This promontory consists of the hills called Zocolaro and Calanna, and of a ridge of inferior height which connects them. (See Fig. 39.)

Fig. 39.



A, Zocolaro.

B, Monte di Calanna.

C, Plain at the head of the Valley of Calanna.

a, Lava of 1819 descending the precipice and flowing through the valley.*b*, Lavas of 1811 and 1819 flowing round the hill of Calanna.

It happened in 1811 and 1819 that the flows of lava overtopped the ridge intervening between the hills of Zocolaro and Calanna, so that they fell in a cascade over a lofty precipice, and began to fill up the valley of Calanna. (*a*, Fig. 39.) Other portions of the same lava-current (*b*) flowed round the promontory, and they exhibit one of the peculiar characteristics of such streams, namely, that of becoming solid externally, even while yet in motion. Instead of thinning out gradually at their edges, their sides may often be compared to two rocky walls, which are sometimes inclined at an angle of between thirty and forty degrees. When such streams are turned from their course by a projecting rock, they move right onwards

in a new direction ; and in the Valley of Calanna a considerable space has thus been left between the steep sides of the lavas *b b*, so deflected, and the precipitous escarpment of Zocolaro, A, which bounds the plain C.

Lavas and Breccias.—In regard to the volcanic masses which are intersected by dikes in the Val del Bove, they consist in great part of greystone lavas, of an intermediate character between basalt and trachyte, and partly of porphyritic lava, resembling trachyte, but to which that name cannot, according to Von Buch and G. Rose, be in strictness applied, because the felspar belongs to the variety called Labradorite. There is great similarity in the composition of the ancient and modern lavas of Etna, both consisting of felspar, augite, olivine, and titaniferous iron. The alternating breccias are made up of scoriæ, sand, and angular blocks of lava. Many of these fragments may have been thrown out by volcanic explosions, which falling on the hardened surface of moving lava-currents, may have been carried to a considerable distance. It may also happen that when lava advances very slowly, in the manner of the flow of 1819, the angular masses resulting from the frequent breaking of the mass, as it rolls over upon itself, may produce these breccias. It is at least certain that the upper portion of the lava-currents of 1811 and 1819 now consist of angular masses to the depth of many yards. D'Aubuisson has compared the surface of one of the ancient lavas of Auvergne to that of a river suddenly frozen over by the stoppage of immense fragments of drift-ice, a description perfectly applicable to these modern Etnean flows. The thickness of the separate beds of conglomerate or breccia which are seen in the same vertical section is often extremely different,

varying from 3 to nearly 50 feet, as I observed in the hill of Calanna.

Flood produced by the melting of snow by lava. — It is possible that some of the breccias or conglomerates may be referred to aqueous causes, as great floods occasionally sweep down the flanks of Etna, when eruptions take place in winter, and when the snows are melted by lava. It is true that running water in general exerts no power on Etna, the rain which falls being immediately imbibed by the porous lavas; so that, vast as is the extent of the mountain, it feeds only a few small rivulets, and these, even, are dry throughout the greater portion of the year. The enormous rounded boulders, therefore, of felspar-porphyry and basalt, a line of which can be traced from the sea, from near Giardini, by Mascali, and Zafarana, to the "Val del Bove," would offer a perplexing problem to the geologist, if history had not preserved the memorials of a tremendous flood which happened in this district in the year 1755. It appears that two streams of lava flowed in that year, on the 2d of March, from the highest crater: they were immediately precipitated upon an enormous mass of snow which then covered the whole mountain, and was extremely deep near the summit. The sudden melting of this frozen mass, by a fiery torrent three miles in length, produced a frightful inundation, which devastated the sides of the mountain for eight miles in length, and afterwards covered the lower flanks of Etna, where they were less steep, together with the plains near the sea, with great deposits of sand, scoriæ, and blocks of lava.

Many absurd stories circulated in Sicily respecting this event; such as that the water was boiling, and that it was vomited from the highest crater; that it was as

salt as the sea, and full of marine shells; but these were mere inventions, to which Recupero, although he relates them as tales of the mountaineers, seems to have attached rather too much importance.

Floods of considerable violence have also been produced on Etna by the fall of heavy rains, aided, probably, by the melting of snow. By this cause alone, in 1761, sixty of the inhabitants of Acicatena were killed, and many of their houses swept away.*

Glacier covered by a lava-stream. — A remarkable discovery was made on Etna in 1828 of a great mass of ice, preserved for many years, perhaps for centuries, from melting, by the singular accident of a current of red-hot lava having flowed over it. The following are the facts in attestation of a phenomenon which must at first sight appear of so paradoxical a character. The extraordinary heat experienced in the South of Europe, during the summer and autumn of 1828, caused the supplies of snow and ice which had been preserved in the spring of that year, for the use of Catania and the adjoining parts of Sicily and the island of Malta, to fail entirely. Great distress was consequently felt for want of a commodity regarded in those countries as one of the necessaries of life rather than an article of luxury, and the abundance of which contributes in some of the larger cities to the salubrity of the water and the general health of the community. The magistrates of Catania applied to Signor M. Gammellaro, in the hope that his local knowledge of Etna might enable him to point out some crevice or natural grotto on the mountain, where drift snow was still preserved. Nor were they disappointed; for he had long suspected that a small mass of perennial ice at

* Ferrara, *Descriz. dell' Etna*, p. 116.

the foot of the highest cone was part of a large and continuous glacier covered by a lava-current. Having procured a large body of workmen, he quarried into this ice, and proved the super-position of the lava for several hundred yards, so as completely to satisfy himself that nothing but the subsequent flowing of the lava over the ice could account for the position of the glacier. Unfortunately for the geologist, the ice was so extremely hard, and the excavation so expensive, that there is no probability of the operations being renewed.

On the first of December, 1828, I visited this spot, which is on the south-east side of the cone, and not far above the Casa Inglese ; but the fresh snow had already nearly filled up the new opening, so that it had only the appearance of the mouth of a grotto. I do not, however, question the accuracy of the conclusion of Signor Gemmellaro, who, being well acquainted with all the appearances of drift snow in the fissures and cavities of Etna, had recognized, even before the late excavations, the peculiarity of the position of the ice in this locality. We may suppose that, at the commencement of the eruption, a deep mass of drift snow had been covered by volcanic sand showered down upon it before the descent of the lava. A dense stratum of this fine dust mixed with scoriae is well known to be an extremely bad conductor of heat ; and the shepherds in the higher regions of Etna are accustomed to provide water for their flocks during summer, by strewing a layer of volcanic sand a few inches thick over the snow, which effectually prevents the heat of the sun from penetrating.

Suppose the mass of snow to have been preserved from liquefaction until the lower part of the lava had

consolidated, we may then readily conceive that a glacier thus protected, at the height of ten thousand feet above the level of the sea, would endure as long as the snows of Mont Blanc, unless melted by volcanic heat from below. When I visited the great crater in the beginning of winter (December 1st, 1828), I found the crevices in the interior encrusted with thick ice, and in some cases hot vapours were actually streaming out between masses of ice and the rugged and steep walls of the crater.

After the discovery of Signor Gemmellaro, it would not be surprising to find in the cones of the Icelandic volcanos, which are covered for the most part with perpetual snow, repeated alternations of lava-streams and glaciers. We have, indeed, Lieutenant Kendall's authority for the fact that Deception Island, in New South Shetland, lat. $62^{\circ} 55'$ S., is principally composed of alternate layers of ashes and ice.*

Origin of the Val del Bove. — We cannot ascribe this valley to the action of running water ; for if it had been excavated exclusively by that power, its depth would have increased in the descent ; whereas, on the contrary, the precipices are most lofty at the upper extremity, and diminish gradually on approaching the lower region of the volcano.

Dr. Daubeny states, that during the eruption of Vesuvius in 1834, the mountain, and all the adjacent country was violently shaken on the night of August 24. At the same time, two small conical hillocks of volcanic matter which existed in the great crater disappeared. They do not seem to have been ejected, or blown into the air, but to have been actually swallowed up in some internal cavity.

* Journ. of Roy. Geograph. Soc. vol. i. p. 64.

It is recorded, as will be stated in the history of earthquakes, that in the year 1772 a great subsidence took place on Papandayang, the largest volcano in the island of Java, an extent of ground *fifteen miles in length and six in breadth*, covered by no less than forty villages, was engulfed, and the cone lost 4000 feet of its height. So also the summit of Carguairazo, one of the loftiest of the Andes of Quito, fell in on the 19th July, 1698 ; and another mountain of still greater altitude in the same chain, called Capac Urcu, a short time before the conquest of America by the Spaniards.

Now we might imagine a similar event, or a series of subsidences to have formerly occurred on the eastern side of Etna, although such catastrophes have not been witnessed in modern times, or only on a very trifling scale. A narrow ravine, about a mile long, twenty feet wide, and from twenty to thirty-six in depth, has been formed, within the historical era, on the flanks of the volcano, near the town of Mascalucia ; and a small circular tract, called the Cisterna, near the summit, sank down in the year 1792, to the depth of about forty feet, and left on all sides of the chasm a vertical section of the beds, exactly resembling those which are seen in the precipices of the Val del Bove. At some remote periods, therefore, we might suppose more extensive portions of the mountain to have fallen in during great earthquakes.

Structure and Origin of the Cone of Etna. — Our data for speculating on the manner in which the cone of Etna has acquired its present dimensions and internal structure are very imperfect, because it is on its eastern side only, in the Val del Bove, that we see a deep section exposed. Even here we obtain no insight

into the interior composition of the mountain beyond a depth of between three and four thousand feet below the base of that highest cone, which has been several times destroyed and renewed. The precipices seen at the head of the Val del Bove, in the escarpment called the Serre del Solfizio, exhibit merely the same series of alternating lavas and breccias, which descending with a general dip towards the sea, form the boundary cliffs of all other parts of the Val del Bove. If then we estimate the height of Etna at about 11,000 feet, we may say that we know from actual observation less than one half of its component materials, assuming it to extend downwards to the level of the sea ; namely, first, the highest cone, which is about 1000 feet above its base ; and, secondly, the alternations of lava, tuff, and volcanic breccia, which constitute the rocks between the Cisterna, near the base of the upper cone, and the foot of the precipices at the head of the Val del Bove. At the lowest point to which the vertical section extends, there are no signs of any approach to a termination of the purely volcanic mass, which may perhaps penetrate many thousand feet farther downwards. There is, indeed, a rock called Rocca Giannicola, near the foot of the great escarpment, which consists of a large mass between 150 and 200 feet wide, not divided into beds, and almost resembling granite in its structure, although agreeing very closely in mineral composition with the lavas of Etna in general.* This mass may doubtless be taken as a representative of those crystalline or plutonic formations which would be met with in abundance if we could descend to greater depths in the direction of the central axis of the mountain. For a

* Hoffmann, *Geognost. Beobachtungen*, p. 701. Berlin, 1839.

great body of geological evidence leads us to conclude, that rocks of this class result from the consolidation, under great pressure of melted matter, which has risen up and filled rents and chasms, such, for example, as may communicate with the principal and minor vents of eruption in a volcano like Etna.

But, if we speculate on the nature of the formations which the lava may have pierced in its way upwards, we may fairly presume that a portion of these consist of marine tertiary rocks, like those of the neighbouring Val di Noto, or those which skirt the borders of the Etnean cone, on its southern and eastern sides. Etna may, in fact, have been at first an insular volcano, raising its summit but slightly above the level of the sea, but we have no grounds for concluding that any of the beds exposed [in the deep section of the Val del Bove, have formed a part of such a marine accumulation. On the contrary, all the usual signs of subaqueous origin are wanting ; and even if we believe the foundations of the mountain to have been laid in the sea, we could not expect this portion to be made visible in sections which only proceed downwards from the summit through one half the thickness of the mountain, especially as the highest points attained by the tertiary strata in other parts of Sicily very rarely exceed 3000 feet above the sea.

On the eastern and southern base of Etna, a marine deposit, already alluded to, is traced up to the height of 800 or 1000 feet, before it becomes concealed beneath that covering of modern lavas which is continually extending its limits during successive eruptions, and prevents us from ascertaining how much higher the marine strata may ascend. As the imbedded shells belong almost entirely to species now inhabiting the

Mediterranean, it is evident that there has been here an upheaval of the region at the base of Etna at a very modern period. It is fair, therefore, to infer that the volcanic nucleus of the mountain, partly perhaps of submarine, and partly of subaërial origin, participated in this movement, and was carried up bodily. Now, in proportion as a cone gains height by such a movement, combined with the cumulative effects of eruptions, throwing out matter successively from one or more central vents, the hydrostatic pressure of the columns of lava augment with their increasing height, until the time arrives when the flanks of the cone can no longer resist the increased pressure; and from that period they give way more readily, lateral outbursts becoming more frequent. Hence, independently of any local expansion of the fractured volcanic mass, those general causes by which the modern tertiary strata of a great part of Sicily have been raised to the height of several thousand feet above their original level, would tend naturally to render the discharge of lava and scoriæ from the summit of Etna less copious, and the lateral discharge greater.

If, then, a conical or dome-shaped mass of volcanic materials was accumulated to the height of 4000, or perhaps 7000 feet, before the upward movement began, or what is much more probable, during the continuance of the upward movement, that ancient mass would not be buried under the products of newer eruptions, because these last would then be poured out chiefly at a lower level.

Since I visited Etna in 1828, M. de Beaumont has published a most valuable memoir on the structure and origin of that mountain, which he examined in 1834 *;

* *Mém. pour servir, &c. tom. iv. Paris, 1838.*

and an excellent description of it has also appeared in the posthumous work of Hoffmann.*

In M. de Beaumont's essay, in which he has explained his views with uncommon perspicuity and talent, he maintains that all the alternating stony and fragmentary beds, more than 3000 feet thick, which are exposed in the Val del Bove, were formed originally on a surface so nearly flat that the slope never exceeded three degrees. From this horizontal position they were at length heaved up suddenly (*d'un seul coup*) into a great mountain, to which no important additions have since been made. Prior to this upthrow, a platform is supposed to have existed above the level of the sea, in which various fissures opened; and from these melted matter was poured forth again and again, which spread itself around in thin sheets of uniform thickness. From the same rents issued showers of scoriæ and fragmentary matter, which were spread out so as to form equally uniform and horizontal beds, intervening between the sheets of lava. But although, by the continued repetition of these operations, a vast pile of volcanic matter, 4000 feet or more in thickness, was built up precisely in that region where Etna now rises, and to which nothing similar was produced elsewhere in Sicily, still we are told that Etna was not yet a mountain. No hypothetical diagram has been given to help us to conceive how this great mass of materials of supramarine origin could have been disposed of in horizontal beds, so as not to constitute an eminence towering far above the rest of Sicily; but it is assumed that a powerful force from below at length burst suddenly through the horizontal formation, uplifted it to a considerable height, and caused the beds to be, in many

* *Geognost. Beobachtungen, &c.* Berlin, 1839.

places, highly inclined. This elevatory force was not all expended on a single central point, as Von Buch has imagined in the case of Palma, Teneriffe, or Somma, but rather followed for a short distance a linear direction.*

Among other objections that may be advanced against the theory above proposed, I may mention, first, that the increasing number of dikes as we approach the head of the Val del Bove, or the middle of Etna, and the great thickness of lava, scoriae, and conglomerates in that region, imply that the great centre of eruption was always where it now is, or nearly at the same point, and there must, therefore, have been a tendency, from the beginning, to a conical or dome-shaped arrangement in the ejected materials. Secondly, were we to admit a great number of separate points of eruption, scattered over a plain or platform, there must then have been a great number of cones thrown up over these different vents, and these hills, some of which would probably be as lofty as those now seen on the flanks of Etna, or from 300 to 750 feet in height, would break the continuity of the sheets of lava, while they would become gradually enveloped by them. The ejected materials, moreover, would slope at a high angle on the sides of these cones, and where they fell on the surrounding plain, would form strata thicker near the base of each cone than at a distance.

What then are the facts, it will be asked, to account for which this hypothesis of original horizontality, followed by a single and sudden effort of upheaval, has been invented? It is remarked by M. de Beaumont, "that, in many parts of the boundary precipices of

* De Beaumont, *Mém. pour servir, &c.*, tom. iv. pp. 187, 188.

the Val del Bove, the sheets of lava are inclined at an angle of from 25° to 30° ; sometimes less than half this amount; while, in other places, as near the head of the valley, they are almost horizontal, yet there is a uniformity in the thickness both of the stony and fragmentary beds in which these various slopes are observable. The alternating sheets also of lava, and beds of scoriae, are not only of considerable length but great breadth, whereas modern streams of lava, which are known to have descended a slope of 30° , 20° , or even 10° , form narrow stripes, never accumulate to a great thickness, nor acquire a compact texture, and their thickness varies with every variation of steepness in the declivity down which they flow."

That the uniformity ascribed to the alternating beds in the Val del Bove holds true throughout large areas, I do not deny, yet it is no easy matter to feel certain of the continuity of the same identical beds for hundreds of yards, much less for miles, when their number in the vertical series is so great, and when all are so similar to each other in mineral composition, and, above all, when they are cut through by countless dikes, many of them several yards wide, and often ramifying and crossing each other. If the line of section passes through a stream of lava obliquely, or nearly in the direction of its original course, we may find it continuous for miles, although its breadth, or continuity, if cut through transversely, may be slight.

It may, however, be conceded as most probable that the greater part of these beds were originally less inclined, some of them much less so than now; and their subsequent disturbance is quite consistent with the doctrine before explained of the successive fracturing,

distension, and upheaval of a great cone during a series of eruptions.

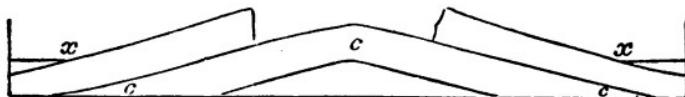
We know not how large a quantity of modern lava may have been poured into the bottom of the Val del Bove, yet we perceive that eruptions breaking forth near the centre of Etna have already made some progress in filling up this great hollow. Even within the memory of persons now living, the rocks of Musara and Capra have, as before stated, lost much of their height and picturesque grandeur by the piling up of recent lavas round their base (see Fig. 37. p. 226.), and the great chasm has intercepted many streams which would otherwise have deluged the fertile region below, as has happened on the side of Catania. The volcanic forces are now labouring, therefore, to repair the breach which subsidence has caused on one side of the great cone; and unless their energy should decline, or a new sinking take place, they may in time efface this inequality. In that event, the restored portion will always be unconformable to the more ancient part, yet it will consist, like it, of alternating beds of lava, scoriæ, and conglomerates, which, with all their irregularities, will have a general slope from the centre and summit of Etna towards the sea. They may also be intersected by dikes or fissures, like those formed in the year 1669 in the plain of San Lio. (See p. 211.)

I shall conclude, then, by remarking that I conceive the general inclination of the alternating stony and fragmentary beds of the Val del Bove, from the axis of Etna towards its circumference or base, and the greater thickness of the volcanic pile as we approach the central parts of the mountain, to be due to the preponderance of eruptions from that centre. These gave rise, from the first, to a dome-shaped mass, which

has ever since been increasing in height and area, being fractured again and again by the expansive force of vapours, and the severed parts made to cohere together more firmly after the solidification of the lava with which every open fissure and chasm has been filled. At the same time the cone may have gained a portion of its height by the elevatory effect of such dislocating movements, and the sheets of lava may have acquired in some places a greater, in others a less, inclination than that which at first belonged to them.

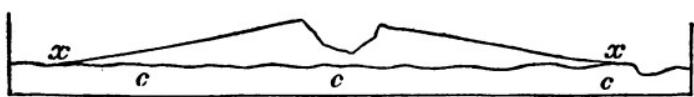
But had the mountain been due solely, or even principally, to upheaval, its structure would have resembled that which geologists have so often recognized in certain dome-shaped hills, or elevated regions, which all consider as having been thrust up by a force from below. In this case there is often an elliptical cavity at the summit, due partly to the fracture of the upraised rocks, but still more to aqueous denudation, as they rose out of the sea. This central cavity, or valley, exposes to view the subjacent formation *c*, Fig. 40.,

Fig. 40.

*Non-volcanic protuberance and valley of elevation.*

and the incumbent mass dips away on all sides from the axis, but has no tendency to thin out near the base of the dome, or at *x*, *x*; whereas at this point the volcanic mass terminates (see Fig. 41.) and allows

Fig. 41.

*Volcanic mountain and crater.*

the fundamental rock *c* to appear at the surface. In the last diagram the more ordinary case is represented of a great hollow or crater at the summit of the volcanic cone, but instead of this, we have seen that in the case of Etna there is a deep lateral depression, called the Val del Bove, the upper part of which approaches near to the central axis, and the origin of which we have attributed to subsidence.

Antiquity of the cone of Etna.—It was before remarked that confined notions in regard to the quantity of past time have tended, more than any other pre-possessions, to retard the progress of sound theoretical views in geology *; the inadequacy of our conceptions of the earth's antiquity having cramped the freedom of our speculations in this science, very much in the same way as a belief in the existence of a vaulted firmament once retarded the progress of astronomy. It was not until Descartes assumed the indefinite extent of the celestial spaces, and removed the supposed boundaries of the universe, that just opinions began to be entertained of the relative distances of the heavenly bodies; and until we habituate ourselves to contemplate the possibility of an indefinite lapse of ages having been comprised within each of the modern periods of the earth's history, we shall be in danger of forming most erroneous and partial views in geology.

Mode of computing the age of volcanos.—If history had bequeathed to us a faithful record of the eruptions of Etna, and a hundred other of the principal active volcanos of the globe, during the last three thousand years,—if we had an exact account of the volume of lava and matter ejected during that period, and the times of their production,—we might, perhaps,

* Vol. I. p. 113.

be able to form a correct estimate of the average rate of the growth of a volcanic cone. For we might obtain a mean result from the comparison of the eruptions of so great a number of vents, however irregular might be the development of the igneous action in any one of them, if contemplated singly during a brief period.

It would be necessary to balance protracted periods of inaction against the occasional outburst of paroxysmal explosions. Sometimes we should have evidence of a repose of seventeen centuries, like that which was interposed in Ischia, between the end of the fourth century, B. C., and the beginning of the fourteenth century of our era.* Occasionally, a tremendous eruption, like that of Jorullo, would be recorded, giving rise, at once, to a considerable mountain.

If we desire to approximate to the age of a cone such as Etna, we ought first to obtain some data in regard to the thickness of matter which has been added during the historical era, and then endeavour to estimate the time required for the accumulation of such alternating lavas and beds of sand and scoriæ as are superimposed upon each other in the Val del Bove; afterwards we should try to deduce, from observations on other volcanos, the more or less rapid increase of burning mountains in all the different stages of their growth.

Mode of increase of volcanos analogous to that of exogenous trees. — There is a considerable analogy between the mode of increase of a volcanic cone and that of trees of *exogenous* growth. These trees augment, both in height and diameter, by the successive appli-

* See p. 158.

cation externally of cone upon cone of new ligneous matter; so that if we make a transverse section near the base of the trunk, we intersect a much greater number of layers than nearer to the summit. When branches occasionally shoot out from the trunk, they first pierce the bark, and then, after growing to a certain size, if they chance to be broken off, they may become inclosed in the body of the tree, as it augments in size, forming knots in the wood, which are themselves composed of layers of ligneous matter, cone within cone.

In like manner, a volcanic mountain, as we have seen, consists of a succession of conical masses enveloping others, while lateral cones, having a similar internal structure, often project, in the first instance, like branches from the surface of the main cone, and then becoming buried again, are hidden like the knots of a tree.

We can ascertain the age of an oak or pine by counting the number of concentric rings of annual growth seen in a transverse section near the base, so that we may know the date at which the seedling began to vegetate. The Baobab-tree of Senegal (*Adansonia digitata*) is supposed to exceed almost any other in longevity; Adanson inferred that one which he measured, and found to be thirty feet in diameter, had attained the age of 5150 years. Having made an incision to a certain depth, he first counted three hundred rings of annual growth, and observed what thickness the tree had gained in that period. The average rate of growth of younger trees, of the same species, was then ascertained, and the calculation made according to a supposed mean rate of increase. De Candolle considers it not improbable that the celebrated Tax-

odium of Chapultepec, in Mexico (*Cupressus disticha* Linn.), which is 117 feet in circumference, may be still more aged.*

It is, however, impossible, until more data are collected respecting the average intensity of the volcanic action, to make any thing like an approximation to the age of a cone like Etna ; because, in this case, the successive envelopes of lava and scoriæ are not continuous, like the layers of wood in a tree, and afford us no definite measure of time. Each conical envelope is made up of a great number of distinct lava-currents and showers of sand and scoriæ, differing in quantity, and which may have been accumulated in unequal periods of time. Yet we cannot fail to form the most exalted conception of the antiquity of this mountain, when we consider that its base is about ninety miles in circumference ; so that it would require ninety flows of lava, each a mile in breadth at their termination, to raise the present foot of the volcano as much as the average height of one lava-current.

There are no records within the historical era which lead to the opinion that the altitude of Etna has materially varied within the last two thousand years. Of the eighty most conspicuous minor cones which adorn its flanks, only one of the largest, Monti Rossi, has been produced within the times of authentic history. Even this hill, thrown up in the year 1669, although 450 feet in height, only ranks as a cone of second magnitude. Monte Minardo, near Bronte, rises, even now, to the height of 750 feet, although its base has been elevated by more modern lavas and ejections. The dimensions of these larger cones appear to bear testimony to *paroxysms* of volcanic activity, after which

* On the Longevity of Trees, *Bibliot. Univ.*, May, 1831.

we may conclude, from analogy, that the fires of Etna remained dormant for many years — since nearly a century of rest has sometimes followed a violent eruption in the historical era. It must also be remembered, that of the small number of eruptions which occur in a century, one only is estimated to issue from the summit of Etna for every two that proceed from the sides. Nor do all the lateral eruptions give rise to such cones as would be reckoned amongst the smallest of the eighty hills above enumerated ; some of them produce merely insignificant monticules, which are soon afterwards buried by showers of ashes.

How many years then must we not suppose to have been expended in the formation of the eighty cones ? It is difficult to imagine that a fourth part of them have originated during the last thirty centuries. But if we conjecture the whole of them to have been formed in twelve thousand years, how inconsiderable an era would this portion of time constitute in the history of the volcano ! If we could strip off from Etna all the lateral monticules now visible, together with the lavas and scoriæ that have been poured out from them, and from the highest crater, during the period of their growth, the diminution of the entire mass would be extremely slight ! Etna might lose, perhaps, several miles in diameter at its base, and some hundreds of feet in elevation ; but it would still be the loftiest of Sicilian mountains, studded with other cones, which would be recalled, as it were, into existence by the removal of the rocks under which they are now buried.

There seems nothing in the deep sections of the Val del Bove to indicate that the lava-currents of remote periods were greater in volume than those of

modern times ; and there are abundant proofs that the countless beds of solid rock and scoriæ were accumulated, as now, in succession. On the grounds, therefore, already explained, we must infer that a mass so many thousand feet in thickness must have required an immense series of ages anterior to our historical periods for its growth ; yet the whole must be regarded as the product of a modern portion of the tertiary epoch. Such, at least, is the conclusion that seems to follow from geological data, which show that the oldest parts of the mountain, if not of posterior date to the marine strata around its base, were at least of coeval origin.

Whether signs of diluvial waves are observable on Etna. — Some geologists contend, that the sudden elevation of large continents from beneath the waters of the sea have again and again produced waves which have swept over vast regions of the earth, and left enormous rolled blocks strewed upon the surface.* That there are signs of local floods of extreme violence, on various parts of the surface of the dry land, is incontrovertible, and I have endeavoured to point out causes which must for ever continue to give rise to such phenomena ; but such appearances afford no geological proof of a general cataclysm. It is clear that no devastating wave has passed over the forest zone of Etna since any of the lateral cones before mentioned were thrown up ; for none of these heaps of loose sand and scoriæ could have resisted for a moment the denuding action of a violent flood.

To some, perhaps, it may appear that hills of such incoherent materials cannot be of very great antiquity, because the mere action of the atmosphere must, in

* Sedgwick, Anniv. Address to the Geol. Soc., p. 35. Feb. 1831.

the course of several thousand years, have obliterated their original forms. But there is no weight in this objection ; for the older hills are covered with trees and herbage, which protect them from waste ; and in regard to the newer ones, such is the porosity of their component materials, that the rain which falls upon them is instantly absorbed, and, for the same reason that the rivers on Etna have a subterranean course, there are none descending the sides of the minor cones.

No sensible alteration has been observed in the form of these cones since the earliest periods of which there are memorials ; and there seems no reason for anticipating that in the course of the next ten thousand or twenty thousand years they will undergo any great alteration in their appearance, unless they should be shattered by earthquakes or covered by volcanic ejections.

In other parts of Europe, as in Auvergne and Velay, in France, similar loose cones of scoriæ, probably of higher antiquity than the whole mass of Etna, stand uninjured at inferior elevations above the level of the sea.

CHAPTER XIV.

Volcanic eruption in Iceland in 1783 — New island thrown up — Lava-currents of Skaptár Jokul, in same year — Their immense volume — Eruption of Jorullo in Mexico — Humboldt's theory of the convexity of the plain of Malpais — Eruption of Galongoon in Java — Submarine volcanos — Graham island, formed in 1831 — Volcanic archipelagos — The Canaries — Teneriffe — Cones thrown up in Lancerote, 1730–36 — Santorin and its contiguous isles — Barren island, in the Bay of Bengal — Mineral composition of volcanic products.

Volcanic eruptions in Iceland. — WITH the exception of Etna and Vesuvius, the most complete chronological records of a series of eruptions are those of Iceland; for their history reaches as far back as the ninth century of our era; and, from the beginning of the twelfth century, there is clear evidence that, during the whole period, there has never been an interval of more than forty, and very rarely one of twenty years, without either an eruption or a great earthquake. So intense is the energy of the volcanic action in this region, that some eruptions of Hecla have lasted six years without ceasing. Earthquakes have often shaken the whole island at once, causing great changes in the interior, such as the sinking down of hills, the rending of mountains, the desertion by rivers of their channels, and the appearance of new lakes.* New islands have often been thrown up near the coast, some of which

* Von Hoff, vol. ii. p. 393.

still exist; while others have disappeared, either by subsidences or the action of the waves.

In the interval between eruptions, innumerable hot springs afford vent to subterranean heat, and solfataras discharge copious streams of inflammable matter. The volcanos in different parts of this island are observed, like those of the Phlegræan Fields, to be in activity by turns, one vent often serving for a time as a safety-valve to the rest. Many cones are often thrown up in one eruption, and in this case they take a linear direction, running generally from north-east to south-west, from the north-eastern part of the island, where the volcano Krabla lies, to the promontory Reykianas.

New island thrown up in 1783.—The convulsions of the year 1783 appear to have been more tremendous than any recorded in the modern annals of Iceland; and the original Danish narrative of the catastrophe, drawn up in great detail, has since been substantiated by several English travellers, particularly in regard to the prodigious extent of country laid waste, and the volume of lava produced.* About a month previous to the eruption on the mainland, a submarine volcano burst forth in the sea in lat. $63^{\circ} 25' N.$, long. $23^{\circ} 44' W.$, at a distance of thirty miles in a south-west direction

* The first narrative of the eruption was drawn up by Stephensen, then Chief Justice in Iceland, appointed commissioner by the King of Denmark, for estimating the damage done to the country, that relief might be afforded to the sufferers. Henderson was enabled to correct some of the measurements given by Stephensen, of the depth, width, and length of the lava-currents, by reference to the MS. of Mr. Paulson, who visited the tract in 1794, and examined the lava with attention. (*Journal of a Residence in Iceland, &c.* p. 229.) Some of the principal facts are also corroborated by Dr. Hooker, in his "*Tour in Iceland,*" vol. ii. p. 128.

from Cape Reykianas, and ejected so much pumice, that the ocean was covered with that substance to the distance of 150 miles, and ships were considerably impeded in their course. A new island was thrown up, consisting of high cliffs, within which fire, smoke, and pumice were emitted from two or three different points. This island was claimed by his Danish Majesty, who denominated it Nyðe, or the New Island; but before a year had elapsed, the sea resumed its ancient domain, and nothing was left but a reef of rocks from five to thirty fathoms under water.

Great eruption of Skaptár Jokul. — Earthquakes, which had long been felt in Iceland, became violent on the 11th of June, 1783, when Skaptár Jokul, distant nearly two hundred miles from Nyðe, threw out a torrent of lava, which flowed down into the river Skaptâ, and completely dried it up. The channel of the river was between high rocks, in many places from four hundred to six hundred feet in depth, and near two hundred in breadth. Not only did the lava fill up this great defile to the brink, but it overflowed the adjacent fields to a considerable extent. The burning flood, on issuing from the confined rocky gorge, was then arrested for some time by a deep lake, which formerly existed in the course of the river, between Skaptardal and Aa, which it entirely filled. The current then advanced again, and reaching some ancient lava full of subterraneous caverns, penetrated and melted down part of it; and in some places, where the steam could not gain vent, it blew up the rock, throwing fragments to the height of more than 150 feet. On the 18th of June, another ejection of liquid lava rushed from the volcano, which flowed down with amazing velocity over the surface of the first stream. By the damming up

of the mouths of some of the tributaries of the Skaptâ, many villages were completely overflowed with water, and thus great destruction of property was caused. The lava, after flowing for several days, was precipitated down a tremendous cataract called Stapafoss, where it filled a profound abyss, which that great waterfall had been hollowing out for ages, and, after this, the fiery current again continued its course.

On the 3d of August, fresh floods of lava still pouring from the volcano, a new branch was sent off in a different direction; for the channel of the Skaptâ was now so entirely choked up, and every opening to the west and north so obstructed, that the melted matter was forced to take a new course, so that it ran in a south-east direction, and discharged itself into the bed of the river Hverfisflot, where a scene of destruction scarcely inferior to the former was occasioned. These Icelandic lavas (like the ancient streams which are met with in Auvergne, and other provinces of Central France), are stated by Stephensen to have accumulated to a prodigious depth in narrow rocky gorges; but when they came to wide alluvial plains, they spread themselves out into broad burning lakes, sometimes from twelve to fifteen miles wide, and one hundred feet deep. When the "fiery lake" which filled up the lower portion of the valley of the Skaptâ had been augmented by new supplies, the lava flowed up the course of the river to the foot of the hills from whence the Skaptâ takes its rise. This affords a parallel case to one which can be shown to have happened at a remote era in the volcanic region of the Vivarais in France, where lava issued from the cone of Thueyts, and while one branch ran down, another more powerful stream flowed up the channel of the river Ardêche.

The sides of the valley of the Skaptâ present superb ranges of basaltic columns of older lavas, resembling those which are laid open in the valleys descending from Mont Dor in Auvergne, where more modern lava-currents, on a scale very inferior in magnitude to those of Iceland, have also usurped the beds of the existing rivers. The eruption of Skaptár Jokul did not entirely cease till the end of two years; and when Mr. Paulson visited the tract eleven years afterwards, in 1794, he found columns of smoke still rising from parts of the lava, and several rents filled with hot water.*

Although the population of Iceland was very much scattered, and did not exceed fifty thousand, no less than twenty villages were destroyed, besides those inundated by water; and more than nine thousand human beings perished, together with an immense number of cattle, partly by the depredations of the lava, partly by the noxious vapours which impregnated the air, and, in part, by the famine caused by showers of ashes throughout the island, and the desertion of the coasts by the fish.

Immense volume of the lava.—But the extraordinary volume of melted matter produced in this eruption deserves the particular attention of the geologist. Of the two branches, which flowed in nearly opposite directions, the greatest was fifty, and the lesser forty, miles in length. The extreme breadth which the Skaptâ branch attained in the low countries was from twelve to fifteen miles, that of the other about seven. The ordinary height of both currents was one hundred feet, but in narrow defiles it sometimes amounted to

* Henderson's Journal, &c. p. 228.

six hundred. A more correct idea will be formed of the dimensions of the two streams, if we consider how striking a feature they would now form in the geology of England, had they been poured out on the bottom of the sea after the deposition, and before the elevation of our secondary and tertiary rocks. The same causes which have excavated valleys through parts of our marine strata, once continuous, might have acted with equal force on the igneous rocks, leaving, at the same time, a sufficient portion undestroyed to enable us to discover their former extent. Let us, then, imagine the termination of the Skaptâ branch of lava to rest on the escarpment of the inferior and middle oolite, where it commands the vale of Gloucester. The great platform might be one hundred feet thick, and from ten to fifteen miles broad, exceeding any which can be found in Central France. We may also suppose great tabular masses to occur at intervals, capping the summit of the Cotswold Hills between Gloucester and Oxford, by Northleach, Burford, and other towns. The wide valley of the Oxford clay would then occasion an interruption for many miles; but the same rocks might recur on the summit of Cumnor and Shotover Hills, and all the other oolitic eminences of that district. On the chalk of Berkshire, extensive plateaus, six or seven miles wide, would again be formed; and, lastly, crowning the highest sands of Highgate and Hampstead, we might behold some remnants of the current five or six hundred feet in thickness, causing those hills to rival, or even to surpass, in height, Salisbury Craigs and Arthur's Seat.

The distance between the extreme points here indicated would not exceed ninety miles in a direct line; and we might then add, at the distance of nearly two

hundred miles from London, along the coast of Dorsetshire and Devonshire, for example, a great mass of igneous rocks, to represent those of contemporary origin, which were produced beneath the level of the sea, where the island of Nyöe rose up.

Volume of ancient and modern flows of lava compared.— Yet, gigantic as must appear the scale of these modern volcanic operations, we must be content to regard them as perfectly insignificant in comparison to currents of the primeval ages, if we embrace the theoretical views of some geologists of great celebrity. Thus, we are informed by Professor Brongniart, in his last work, that “aux époques géognostiques anciennes, tous les phénomènes géologiques se passoient dans des dimensions *centuples* de celles qu'ils présentent aujourd'hui.”* Had Skaptár Jokul, therefore, been a volcano of the olden-time, it would have poured forth lavas at a single eruption a hundred times more voluminous than those which were witnessed by the present generation in 1783. But this can never have been intended by M. Brongniart; for were we to multiply the two currents before described by a hundred, and first assume that their height and breadth remain the same, they would stretch out to the length of nine thousand miles, or about half as far again as from the pole to the equator. If, on the other hand, we suppose their length and breadth to remain the same, and multiply their height in an equal proportion, the mean elevation of the volcanic mass becomes ten thousand feet, and its greatest more than double that of the Himalaya mountains. It will immediately be granted

* Tableau des Terrains qui composent l'Ecorce du Globe, p. 52.
Paris, 1829.

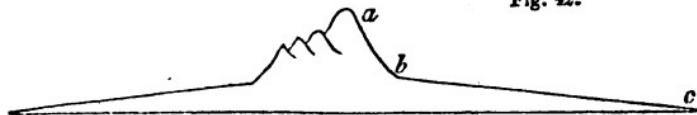
that, among the older formations, no igneous rock of such colossal magnitude has yet been met with; nay, it would be most difficult to point out a mass of ancient date, distinctly referable to a single eruption, which should even rival in volume the matter poured out from Skaptár Jokul in 1783.

Eruption of Jorullo in 1759.—As another example of the stupendous scale of modern volcanic eruptions, I may mention that of Jorullo in Mexico, in 1759. The great region to which this mountain belongs has already been described. The plain of Malpais forms part of an elevated platform, between two and three thousand feet above the level of the sea, and is bounded by hills composed of basalt, trachyte, and volcanic tuff, clearly indicating that the country had previously, though probably at a remote period, been the theatre of igneous action. From the era of the discovery of the New World to the middle of the last century, the district had remained undisturbed, and the space, now the site of the volcano, which is thirty-six leagues distant from the nearest sea, was occupied by fertile fields of sugar-cane and indigo, and watered by the two brooks Cuitimba and San Pedro. In the month of June, 1759, hollow sounds of an alarming nature were heard, and earthquakes succeeded each other for two months, until, at the end of September, flames issued from the ground, and fragments of burning rocks were thrown to prodigious heights. Six volcanic cones, composed of scoriæ and fragmentary lava, were formed on the line of a chasm which ran in the direction from N.N.E. to S.S.W. The least of these cones was 300 feet in height; and Jorullo, the central volcano, was elevated 1600 feet above the level of the plain. It sent forth great streams of basaltic lava,

containing included fragments of granitic rocks, and its ejections did not cease till the month of February, 1760.*

Humboldt visited the country more than forty years after this occurrence, and was informed by the Indians, that when they returned, long after the catastrophe, to the plain, they found the ground uninhabitable from the excessive heat. When he himself visited the place, there appeared, around the base of the cones, and spreading from them, as from a centre, over an extent of four square miles, a mass of matter of a convex form, about 550 feet high at its junction with the cones, and gradually sloping from them in all directions towards the plain. This mass was still in a

Fig. 42.



a, Summit of Jorullo. *b, c*, Inclined plane sloping at angle of 6° from the base of the cones.

heated state, the temperature in the fissures being on the decrease from year to year, but in 1780 it was still sufficient to light a cigar at the depth of a few inches. On this slightly convex protuberance, the slope of which must form an angle of about 6° with the horizon, were thousands of flattish conical mounds, from six to nine feet high, which, as well as large fissures traversing the plain, acted as fumeroles, giving out clouds of sulphuric acid and hot aqueous vapour. The two small rivers before mentioned disappeared during the eruption, losing themselves below the eastern extremity of the plain, and reappearing as hot springs at its western limit.

* Daubeny on Volcanos, p. 337.

Cause of the convexity of the plain of Malpais. — Humboldt attributed the convexity of the plain to inflation from below; supposing the ground, for four square miles in extent, to have risen up in the shape of a bladder to the elevation of 550 feet above the plain in the highest part. But Mr. Scrope has suggested that the phenomena may be accounted for far more naturally, by supposing that lava flowing simultaneously from the different orifices, and principally from Jorullo, united into a sort of pool or lake. As they were poured forth on a surface previously flat, they would, if their liquidity was not very great, remain thickest and deepest near their source, and diminish in bulk from thence towards the limits of the space which they covered. Fresh supplies were probably emitted successively during the course of an eruption which lasted more than half a year; and some of these, resting on those first emitted, might only spread to a small distance from the foot of the cone, where they would necessarily accumulate to a great height.

The showers, also, of loose and pulverulent matter from the six craters, and principally from Jorullo, would be composed of heavier and more bulky particles near the cones, and would raise the ground at their base, where, mixing with rain, they might have given rise to the stratum of black clay which is described as covering the lava. The small conical mounds (called "hornitos," or little ovens) may resemble those five or six small hillocks which existed in 1823 on the Vesuvian lava, and sent forth columns of vapour, having been produced by the disengagement of elastic fluids heaving up small dome-shaped masses of lava. The fissures mentioned by Humboldt

as of frequent occurrence, are such as might naturally accompany the consolidation of a thick bed of lava, contracting as it congeals; and the disappearance of rivers is the usual result of the occupation of the lower part of a valley or plain by lava, of which there are many beautiful examples in the old lava-currents of Auvergne. The heat of the "hornitos" is stated to have diminished from the first; and Mr. Bullock, who visited the spot many years after Humboldt, found the temperature of the hot spring very low,—a fact which seems clearly to indicate the gradual congelation of a subjacent bed of lava, which from its immense thickness may have been enabled to retain its heat for half a century. The reader may be reminded, that when we thus suppose the lava near the volcano to have been, together with the ejected ashes, more than five hundred feet in depth, we merely assign a thickness which the current of Skaptár Jokul attained in some places in 1783.

Hollow sound of the plain when struck.—Another argument adduced in support of the theory of inflation from below, was, the hollow sound made by the steps of a horse upon the plain; which, however, proves nothing more than that the materials of which the convex mass is composed are light and porous. The sound called "rimbombo" by the Italians is very commonly returned by *made ground* when struck sharply; and has been observed not only on the sides of Vesuvius and other volcanic cones where there is a cavity below, but in plains such as the Campagna di Roma, composed in a great measure of tuff and porous volcanic rocks. The reverberation, however, may perhaps be assisted by grottos and caverns, for these may be as numerous in the lavas of Jorullo as in many

of those of Etna; but their existence would lend no countenance to the hypothesis of a great arched cavity, four square miles in extent, and in the centre 550 feet high.*

No recent eruptions of Jorullo. — In a former edition I stated that I had been informed by Captain Vetch, that in 1819 a tower at Guadalaxara was thrown down by an earthquake, and that ashes, supposed to have come from Jorullo, fell at the same time at Guanajuato, a town situated 140 English miles from the volcano. But Mr. Burkart, a German director of mines, who examined Jorullo in 1827, ascertained that there had been no eruption there since Humboldt's visit in 1803. He went to the bottom of the crater, and observed a slight evolution of sulphurous acid vapours, but the "hornitos" had entirely ceased to send forth steam. During the twenty-four years intervening between his visit and that of Humboldt, vegetation had made great progress on the flanks of the new hills, the rich soil of the surrounding country was once more covered with luxuriant crops of sugar-cane and indigo, and there was an abundant growth of natural underwood on all the uncultivated tracts.†

Galongoon, Java, 1822. — The mountain of Galongoon (or Galung Gung) was in 1822 covered by a dense forest, and situated in a fruitful and thickly-peopled part of Java. There was a circular hollow at its summit, but no tradition existed of any former eruption. In July, 1822, the waters of the river Kunir, one of those which flowed from its flanks, became for a time hot and turbid. On the 8th of October following a loud explosion was heard, the earth shook, and

* See Scrope on Volcanos, p. 267.

† Leonhard and Brönn's Neues Jahrbuch, 1835, p. 36.

immense columns of hot water and boiling mud, mixed with burning brimstone, ashes, and lapilli of the size of nuts, were projected from the mountain like a water-spout, with such prodigious violence that large quantities fell beyond the river Tandoi, which is forty miles distant. Every valley within the range of this eruption became filled with a burning torrent, and the rivers, swoln with hot water and mud, overflowed their banks, and carried away great numbers of the people, who were endeavouring to escape, and the bodies of cattle, wild beasts, and birds. A space of twenty-four miles between the mountain and the river Tandoi was covered to such a depth with bluish mud that people were buried in their houses, and not a trace of the numerous villages and plantations throughout that extent was visible. Within this space the bodies of those who perished were buried in mud and concealed, but near the limits of the volcanic action they were exposed, and strewed over the ground in great numbers, partly boiled and partly burnt.

It was remarked, that the boiling mud and cinders were projected with such violence from the mountain, that while many remote villages were utterly destroyed and buried, others much nearer the volcano were scarcely injured.

The first eruption lasted nearly five hours, and on the following days the rain fell in torrents, and the rivers, densely charged with mud, deluged the country far and wide. At the end of four days (October 12th) a second eruption occurred more violent than the first, in which hot water and mud were again vomited, and great blocks of basalt were thrown to the distance of seven miles from the volcano. There was at the same time a violent earthquake, and in one account it is

stated that the face of the mountain was utterly changed, its summits broken down, and one side, which had been covered with trees, became an enormous gulf in the form of a semicircle. This cavity was about midway between the summit and the plain, and surrounded by steep rocks, said to be newly heaped up during the eruption. New hills and valleys are said to have been formed, and the rivers Banjarang and Wulan changed their course, and in one night (October 12th) 2000 persons were killed.

The first intimation which the inhabitants of Bandong received of this calamity on the 8th of October was the news that the river Wulan was bearing down into the sea the dead bodies of men, and the carcasses of stags, rhinoceroses, tigers, and other animals. The Dutch painter Payen determined to travel from thence to the volcano, and he found that the quantity of the ashes diminished as he approached the base of the mountain. He alludes to the altered form of the mountain after the 12th, but does not describe the new semicircular gulf on its side.

The official accounts state that 114 villages were destroyed, and above 4000 persons killed.*

Submarine volcanos.—Although we have every reason to believe that volcanic eruptions as well as earthquakes are common in the bed of the sea, it was not to be expected that many opportunities would occur to scientific observers of witnessing the phenomena. The crews of vessels have sometimes reported that they have seen in different places sulphureous smoke, flame, jets of water, and steam, rising

* Van der Boon Mesch, de Incendiis Montium Javæ, &c. Lugd. Bat. 1826; and Official Report of the President, Baron Van der Capellen; also, Von Buch, Iles Canar. p. 424.

up from the sea, or they have observed the waters greatly discoloured, and in a state of violent agitation, as if boiling. New shoals have also been encountered, or a reef of rocks just emerging above the surface, where previously there was always supposed to have been deep water. On some few occasions the gradual formation of an island by a submarine eruption has been observed, as that of Sabrina, in the year 1811, off St. Michael's, in the Azores. The throwing up of ashes in that case, and the formation of a cone about three hundred feet in height, with a crater in the centre, closely resembled the phenomena usually accompanying a volcanic eruption on land. Sabrina was soon washed away by the waves. Previous eruptions in the same part of the sea were recorded to have happened in 1691 and 1720. The rise of Nyöe, also, a small island off the coast of Iceland, in 1783, has already been alluded to ; and another volcanic isle was produced by an eruption near Reikiavig, on the same coast, in June, 1830.*

Graham Island†, 1831.—We have still more recent and minute information respecting the appearance, in 1831, of a new volcanic island in the Mediterranean, between the S. W. coast of Sicily and that projecting part of the African coast where ancient Carthage

* *Journ. de Géol.* tome i.

† In a former edition, I selected the name of Sciacca out of seven which had been proposed ; but the Royal and Geographical Societies have now adopted Graham Island ; a name given by Captain Senhouse, R. N., the first who succeeded in landing on it. The seven rival names are Nerita, Ferdinand, Hotham, Graham, Corrao, Sciacca, Julia. As the isle was visible for only about three months, this is an instance of a wanton multiplication of synonyms which has scarcely ever been outdone even in the annals of zoology and botany.

stood. The site of the island was not any part of the great shoal, or bank, called "Nerita," as was first asserted, but a spot where Captain W. H. Smyth had found, in his survey a few years before, a depth of more than one hundred fathoms' water.*

The position of the island (lat. $37^{\circ} 8' 30''$ N., long. $12^{\circ} 42' 15''$ E.) was about thirty miles S. W. of Scicca, in Sicily, and thirty-three miles N. E. of Pantelaria.† On the 28th of June, about a fortnight before the eruption was visible, Sir Pulteney Malcolm, in passing over the spot in his ship, felt the shocks of an earthquake, as if he had struck on a sand-bank; and the same shocks were felt on the west coast of Sicily, in a direction from S. W. to N. E. About the 10th of July, John Corrao, the captain of a Sicilian vessel, reported that, as he passed near the place, he saw a column of water like a water-spout, sixty feet high, and eight hundred yards in circumference, rising from the sea, and soon afterwards a dense steam in its place, which ascended to the height of 1800 feet. The same Corrao, on his return from Gergenti, on the 18th of July, found a small island, twelve feet high, with a crater in its centre, ejecting volcanic matter, and immense columns of vapour; the sea around being covered with floating cinders and dead fish. The scoriae were of a chocolate colour, and the water which boiled in the circular basin was of a dingy red. The eruption continued with great violence to the end of the same month; at which time the island was visited by several persons, and, among others, by Captain Swinburne, R. N., and M. Hoffmann, the Prussian geologist. It was then from fifty to ninety

* Phil. Trans. 1832, p. 255.

† Journ. of Roy. Geograph. Soc. 1830-31.

feet in height, and three quarters of a mile in circumference. By the 4th of August it became, according

Fig. 43.



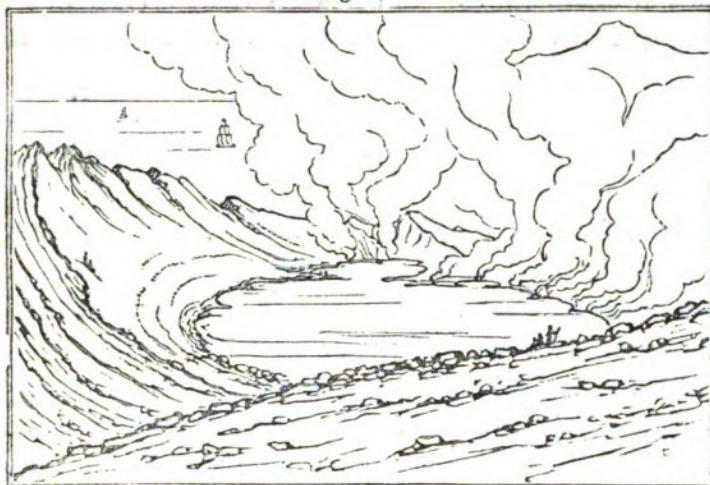
*Form of the cliffs of Graham Island, as seen from S. S. E., distant one mile,
7th August, 1831.**

to some accounts, above 200 feet high, and three miles in circumference; after which it began to diminish in size by the action of the waves, and was only two miles round on the 25th of August; and on the 3d of September, when it was carefully examined by Captain Wodehouse, only three-fifths of a mile in circumference; its greatest height being then 107 feet. At this time the crater was about 780 feet in circumference. On the 29th of September, when it was visited by Mons. C. Prevost, its circumference was reduced to about seven hundred yards. It was composed entirely of incoherent ejected matter, scoriæ, pumice, and lapilli, forming regular strata, some of which are described as having been parallel to the steep inward slope of the crater, while the rest were inclined outwards, like those of Vesuvius.† When the arrangement of the ejected materials has been determined by their falling continually on two steep slopes, that of the external cone and that of the crater,

* Phil. Trans., part ii., 1832, reduced from drawings by Captain Wodehouse, R. N.

† See memoir by M. C. Prevost, Ann. des Sci. Nat. tom. xxiv.

Fig. 44.

*View of the interior of Graham Island, 29th Sept. 1831.*

which is always a hollow inverted cone, a transverse section would probably resemble that given in the an-

Fig. 45.

*Graham Island, 29th Sept. 1831.**

* In the annexed sketch (Fig. 45.), drawn by M. Joinville, who accompanied M. C. Prevost, the beds seem to slope towards the centre of the crater; but I am informed by Mr. Prevost that these lines were not intended by the artist to represent the dip of the beds.

nexed figure (46.). But when I visited Vesuvius, in 1828, I saw no beds of scoriæ inclined towards the



Fig. 46.

axis of the cone (see Fig. 31. p. 182.). Such may have once existed; but the explosions or subsidences, or whatever causes produced the great crater of 1822, had possibly destroyed them.

Few of the pieces of stone thrown out from Graham Island exceeded a foot in diameter. Some fragments of dolomitic limestone were intermixed; but these were the only non-volcanic substances. During the month of August, there occurred on the S. W. side of the new island a violent ebullition and agitation of the sea, accompanied by the constant ascension of a column of dense white steam, indicating the existence of a second vent at no great depth from the surface. Towards the close of October, no vestige of the crater remained, and the island was nearly levelled with the surface of the ocean, with the exception, at one point, of a small monticule of sand and scoriæ. It was reported that, at the commencement of the year following (1832), there was a depth of 150 feet where the island had been: but this account was quite erroneous; for in the early part of that year Captain Swinburne found a shoal and discoloured water there, and towards the end of 1833 a dangerous reef existed, of an oval figure, about three-fifths of a mile in extent. In the centre was a black rock, of the diameter of about twenty-six fathoms, from nine to eleven feet under water; and round this rock are banks of black volcanic stones and loose sand. At the distance of

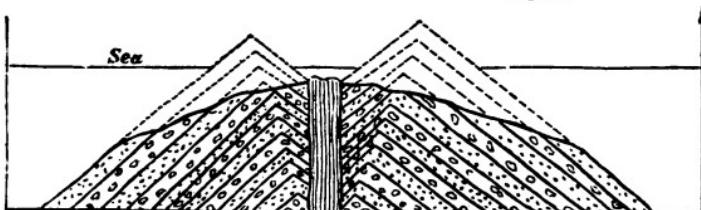
sixty fathoms from this central mass, the depth increased rapidly. There was also a second shoal at the distance of 450 feet S. W. of the great reef, with fifteen feet water over it, also composed of rock, surrounded by deep sea. We can scarcely doubt that the rock in the middle of the larger reef is solid lava, which rose up in the principal crater, and that the second shoal marks the site of the submarine eruption observed in August, 1831, to the S. W. of the island.

From the whole of the facts above detailed, it appears that a hill eight hundred feet or more in height was formed by a submarine volcanic vent, of which the upper part (only about two hundred feet high) emerged above the waters, so as to form an island. This cone must have been equal in size to one of the largest of the lateral volcanos on the flanks of Etna, and about half the height of the mountain Jorullo in Mexico, which was formed in the course of nine months, in 1759. In the centre of the new volcano a large cavity was kept open by gaseous discharges, which threw out scoriæ; and fluid lava probably rose up in this cavity. It is not uncommon for small subsidiary craters to open near the summit of a cone, and one of these may have been formed in the case of Graham Island; a vent, perhaps, connected with the main channel of discharge which gave passage in that direction to elastic fluids, scoriæ, and melted lava. It does not appear that, either from this duct, or from the principal vent, there was any overflowing of lava; but melted rock may have flowed from the flanks or base of the cone (a common occurrence on land), and may have spread in a broad sheet over the bottom of the sea.

The dotted lines in the annexed figure are an imagi-

nary restoration of the upper part of the cone, now removed by the waves : the strong lines represent the part of the volcano which is still under water ; in the centre is a great column, or dike, of solid lava, two hundred feet in diameter, supposed to fill the space by

Fig. 47.

*Supposed section of Graham Island. (C. Maclarens.*)*

which the gaseous fluids rose ; and on each side of the dike is a stratified mass of scoriæ and fragmentary lava. The solid nucleus of the reef, where the black rock is now found, withstands the movements of the sea ; while the surrounding loose tuffs are cut away to a somewhat lower level. In this manner the lava, which was the lowest part of the island, or to speak more correctly, which scarcely ever rose above the level of the sea when the island existed, has now become the highest point in the reef.

No appearances observed, either during the eruption or since the island disappeared, give the least support to the opinion promulgated by some writers, that part of the ancient bed of the sea had been lifted up bodily.

The solid products, says Dr. John Davy, whether they consisted of sand, light cinders, or vesicular lava, differed more in form than in composition. The lava contained augite ; and the specific gravity was 2·07 and 2·70. When the light spongy cinder, which floated

* *Geol. of Fife and the Lothians*, p. 41. Edin. 1839.

on the sea, was reduced to fine powder by trituration, and the greater part of the entangled air got rid of, it was found to be of the specific gravity 2·64; and that of some of the sand which fell in the eruption was 2·75*; so that the materials equalled ordinary granites in weight and solidity. The only gas evolved in any considerable quantity was carbonic acid.†

Canary Islands — Teneriffe. — The Peak of Teneriffe, which is about 12,000 feet high, stands, says Von Buch, like a tower encircled by its fosse and bastion. The bastion consists, like the semicircular escarpment of Somma turned towards Vesuvius, of precipitous cliffs, composed of trachyte, basalt, coarse conglomerates, and tuffs, traversed by volcanic dikes, mostly vertical, and of basalt. These cliffs vary in height from 1000 to 1800 feet, and are supposed by Von Buch to have been heaved up into their present position by a force exerted from below, in accordance with the theory proposed by the same author for the origin of the cones of Vesuvius and Etna.

The highest crater of the peak has merely disengaged sulphurous vapours ever since it has been known to Europeans; but an eruption happened in June, 1798, not far from the summit, and others are recorded, which poured out streams of lava from great heights, besides many which have broken out nearer the level of the sea. All these, however, seem to be dependent on one great centre of eruption, or on that open channel communicating between the interior of the earth and the atmosphere, which terminates in the highest crater of the peak.

We may consider Teneriffe, then, as having been from a remote period the principal and habitual vent

* Phil. Trans. 1832, p. 243.

† Ibid. p. 249.

of the volcanic archipelago of the Canaries. The discharges which have taken place in the contiguous isles of Palma, Lancerote, and the rest, may be of a subsidiary kind, and have probably been most frequent and violent when the great crater has been partially sealed up, just as the violent eruptions of Ischia or that of Monte Nuovo coincided with the dormant state of Vesuvius.

Eruption in Lancerote, 1730 to 1736. — The effects of one of these insular eruptions in the Canaries, which happened in Lancerote, between the years 1730 and 1736, were very remarkable ; and a detailed description has been published by Von Buch, who had an opportunity, when he visited that island in 1815, of comparing the accounts transmitted to us of the event, with the present state and geological appearances of the country.* On the first of September, 1730, the earth split open on a sudden two leagues from Yaira. In one night a considerable hill of ejected matter was thrown up ; and a few days later, another vent opened, and gave out a lava-stream, which overran Chinanfaya and other villages. It flowed first rapidly, like water, but became afterwards heavy and slow, like honey. On the 7th of September an immense rock was protruded from the bottom of the lava, with a noise like thunder, and the stream was forced to change its course from N. to N.W., so that St. Catalina and other villages were overflowed.

Whether this mass was protruded by an earthquake,

* This account was principally derived by Von Buch from the MS. of Don Andrea Lorenzo Curbeto, curate of Yaira, the point where the eruption began.— Ueber einen vulcanischen Ausbruch auf der Insel Lanzerote.

or was a mass of ancient lava, blown up like that before mentioned in 1783 in Iceland, is not explained.

On the 11th of September more lava flowed out, and covered the village of Maso entirely, and, for the space of eight days, precipitated itself with a horrible roar into the sea. Dead fish floated on the waters in indescribable multitudes, or were thrown dying on the shore. After a brief interval of repose, three new openings broke forth immediately from the site of the consumed St. Catalina, and sent out an enormous quantity of lapilli, sand, and ashes. On the 28th of October the cattle throughout the whole country dropped lifeless to the ground, suffocated by putrid vapours, which condensed and fell down in drops. On the 1st of December a lava-stream reached the sea, and formed an island, round which dead fish were strewed.

Number of cones thrown up. — It is unnecessary here to give the details of the overwhelming of other places by fiery torrents, or of a storm which was equally new and terrifying to the inhabitants, as they had never known one in their country before. On the 10th of January, 1731, a high hill was thrown up, which, on the same day, precipitated itself back again into its own crater; fiery brooks of lava flowed from it to the sea. On the 3d of February a new cone arose. Others were thrown up in March, and poured forth lava-streams. Numerous other volcanic cones were subsequently formed in succession, till at last their number amounted to about thirty. In June, 1731, during a renewal of the eruptions, all the banks and shores in the western part of the island were covered with dying fish, of different species, some of which had never before been seen. Smoke and flame arose

from the sea, with loud detonations. These dreadful commotions lasted without interruption for *five successive years*, so that a great emigration of the inhabitants became necessary.

Their linear direction. — As to the height of the new cones, Von Buch was assured that the formerly great and flourishing St. Catalina lay buried under hills 400 feet in height ; and he observes that the most elevated cone of the series rose 600 feet above its base, and 1378 feet above the sea, and that several others were nearly as high. The new vents were all arranged *in one line*, about two geographical miles long, and in a direction nearly east and west. If we admit the probability of Von Buch's conjecture, that these vents opened along the line of a cleft, it seems necessary to suppose that this subterranean fissure was only prolonged upwards to the surface by degrees, and that the rent was narrow at first, as is usually the case with fissures caused by earthquakes. Lava and elastic fluids might escape from some point on the rent where there was least resistance, till, the first aperture becoming obstructed by ejections and the consolidation of lava, other orifices burst open in succession along the line of the original fissure. Von Buch found that each crater was lowest on that side on which lava had issued ; but some craters were not breached, and were without any lava-streams. In one of these were open fissures, out of which hot vapours rose, which in 1815 raised the thermometer to 145° Fahrenheit, and was probably at the boiling point lower down. The exhalations seemed to consist of aqueous vapour ; yet they could not be pure steam, for the crevices were encrusted on either side by siliceous sinter (an opal-like hydrate of silica of a white colour), which ex-

tended almost to the middle. This important fact attests the length of time during which chemical processes continue after eruptions, and how open fissures may be filled up laterally by mineral matter, sublimed from volcanic exhalations. The lavas of this eruption covered nearly a third of the whole island, often forming on slightly inclined planes great horizontal sheets several square leagues in area, resembling very much the basaltic platforms of Auvergne.

Pretended distinction between ancient and modern lavas. — One of the new lavas was observed to contain masses of olivine of an olive-green colour, resembling those which occur in one of the lavas of the Vivarais. Von Buch supposes the great crystals of olivine to have been derived from a previously existing basalt melted up by the new volcanos ; but we have scarcely sufficient data to bear out such a conjecture. The older rocks of the island consist, in a great measure, of that kind of basaltic lava called dolerite, sometimes columnar, and partly of common basalt and amygdaloid. Some recent lavas assumed, on entering the sea, a prismatic form, and so much resembled the older lavas of the Canaries, that the only geological distinction which Von Buch appears to have been able to draw between them was, that they did not alternate with conglomerates, like the ancient basalts. Some modern writers have endeavoured to discover, in the abundance of these conglomerates, a proof of the dissimilarity of the volcanic action in ancient and modern times ; but this character is more probably attributable to the difference between submarine operations and those on the land. All the blocks and imperfectly rounded fragments of lava, transported, during the intervals of eruption, by rivers and torrents, into the adjoining

sea, or torn by the continued action of the waves from cliffs which are undermined, must accumulate in stratified breccias and conglomerates, and be covered again and again by other lavas. This is now taking place on the shores of Sicily, between Catania and Trezza, where the sea breaks down and covers the shore with blocks and pebbles of the modern lavas of Etna; and on parts of the coast of Ischia, where numerous currents of trachyte are in like manner undermined in lofty precipices. So often, then, as an island is raised in a volcanic archipelago by earthquakes from the deep, the fundamental and (relatively to all above) the oldest lavas will often be distinguishable from those formed by subsequent eruptions on dry land, by their alternation with beds of sandstone and fragmentary rocks.

The supposed want of identity, then, between the volcanic phenomena of different epochs resolves itself into the marked difference between the operations simultaneously in progress, above and below the waters. Such, indeed, is the source, as was before stated in the First Book (Chap. V.), of many of our strongest theoretical prejudices in geology. No sooner do we study and endeavour to explain submarine appearances, than we feel, to use a common expression, out of our element; and, unwilling to concede that our extreme ignorance of processes now continually going on can be the cause of our perplexity, we take refuge in a "pre-existent order of nature."

Recent formation of oolitic travertin in Lancerote. — Throughout a considerable part of Lancerote, the old lavas are covered by a thin stratum of limestone, from an inch to two feet in thickness. It is of a hard stalactitic nature, sometimes oolitic, like the Jura lime-

stone, and contains fragments of lava and terrestrial shells, chiefly helices and spiral bulimi. It sometimes rises to the height of 800 feet above the level of the sea. Von Buch imagines, that this remarkable superstratum has been produced by the furious north-west storms, which in winter drive the spray of the sea in clouds over the whole island; from whence calcareous particles may be deposited stalactitically. Mr. Darwin informs me that he found a limestone in St. Helena, the harder parts of which correspond precisely to the stone of Lancerote. He attributes the origin of this rock in St. Helena not to the spray of the sea, but to drifting by violent winds of the finer particles of shells from the sea-beach. Some parts of this drift are subsequently dissolved by atmospheric moisture, and redeposited, so as to convert calcareous sand into oolite.

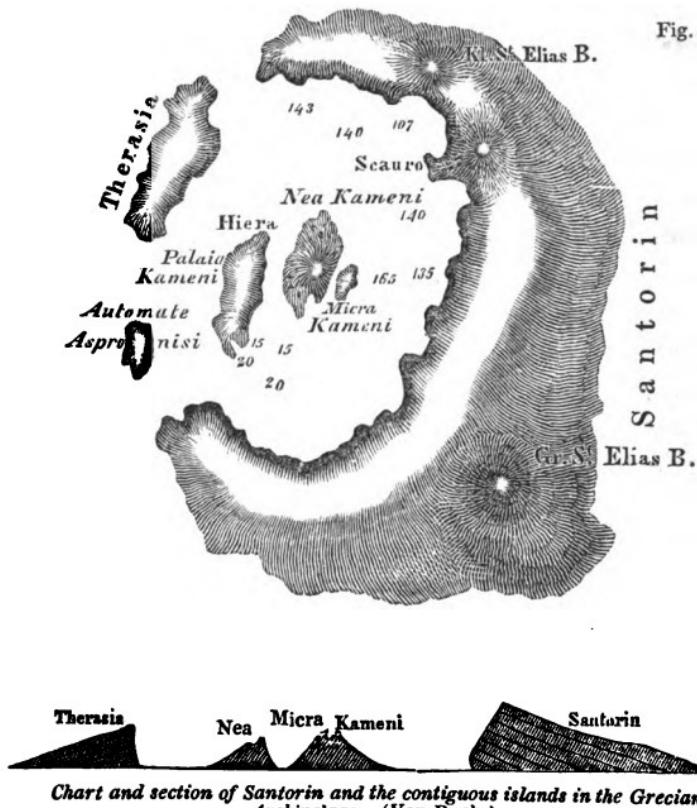
Recent eruption in Lancerote. — From the year 1786 to 1815, when Von Buch visited Lancerote, there had been no eruption; but, in August, 1824, a crater opened near the port of Rescif, and formed, by its ejections, in the space of twenty-four hours, a considerable hill. Violent earthquakes preceded and accompanied this eruption.*

Santorin. — The outer portion of Santorin, in the Grecian archipelago, is composed of three islands, Santorin, Therasia, and Aspronisi, which surround an almost circular gulf of about two leagues in diameter from south to north, and a league and a half from east to west. The island of Santorin itself forms more than two thirds of the circuit, and is composed entirely of volcanic matter, with the exception of its southern

* Féüssac, *Bulletin des Sci. Nat.* tome v. p. 45. 1825. The volcano was still burning when the account here cited was written.

part, which rises to three times the height of the igneous rocks in the island, and is formed of granular limestone and argillaceous schist.* This mountainous part is the original and fundamental nucleus of the isle; and, according to M. Bory de St. Vincent, its strata have the same direction as those of the other isles of the Grecian archipelago, from N.N.W. to S.S.E. Their inclination and fractures have no rela-

Fig. 48.



tion to the position of the newer volcanic rocks, of which the remainder of the group of islands is exclu-

* Virlet, Bull. de la Soc. Géol. de France, tom. iii. p. 103.

sively composed. The volcanic mass, which must be considered as quite an independent formation, consists of alternating beds of trachytic lava, tuff, and conglomerate, which dip on every side from the centre of the gulf to the circumference. Towards the gulf they present uniformly a high and steep escarpment, the precipices in Santorin rising to the height of more than eight hundred feet, and plunging at once into a sea from eight hundred to a thousand feet deep. Each of the islands is capped by an enormous mass of white tufaceous conglomerate, from forty to fifty feet in thickness; which is not pumice, as has often been stated. The beds of lava and tuff, above mentioned, are accumulated in great numbers one upon another, and of unequal thickness: although disposed with great regularity, when viewed as a whole, they are found to be discontinuous, as in Vesuvius, when any particular mass is traced to some distance.

Before discussing the merits of the theory proposed to account for the structure of this volcanic group, it will be desirable to give a brief sketch of its history, so far as it is known. Pliny relates that the separation of Therasia from Thera, or Santorin, took place after a violent earthquake, in the year 236 before the Christian era. From his work, and other authorities, we also learn that the year 186 b. c. gave birth, in the middle of the gulf, to Hiera, or the Sacred Isle, still called Hiera-Nisos, or sometimes Palaia Kameni (Old Burnt Island). There seems to have been no eruption then, but simply an upheaving of solid lava. In the year 19 of our era, Thia (the Divine) made its appearance above the surface of the waters. This small island has no longer a separate existence, having been joined to Hiera, from which it was only 250 paces distant:

Hiera itself increased in size in 726, and in 1427. In 1573, the small island of Micra-Kameni appeared, a small cone and crater, one hundred feet high, raised by successive ejections.

On the 27th of September, 1650, there was an eruption three or four miles north of Santorin, altogether outside of the gulf, immediately after violent earthquakes. It gave rise to no new islet, but greatly elevated the bottom of the sea on the spot. The eruption lasted three months; many houses on Santorin were destroyed; and the vapours of sulphur and hydrogen killed more than fifty persons, and more than one thousand domesticated animals. A wave fifty feet high broke upon the rocks of the Isle of Nio, about four leagues distant, and advanced 350 yards into the interior of the island of Sikino, which is seven leagues off. The sea also broke upon Santorin, overthrew two churches, and exposed to view a village on each side of the mountain of St. Stephen, both of which must have been overwhelmed by showers of volcanic matter during some former eruption.*

Lastly, in 1707 and 1709, Nea-Kameni was produced between Palaia and Micra (old and lesser) Kamenis. This isle was composed originally of two distinct parts, the first which rose was called the White Island — a mass of pumice, extremely porous. Goree the Jesuit, who was then in Santorin, says that the rock “cut like bread,” and that, when the inhabitants landed on it, they found a multitude of full-grown fresh oysters adhering to it, which they eat.† This island was afterwards covered, in great part, by the matter ejected from the crater of the second island,

* Virlet, Bull. de la Soc. Géol. de France, tom. iii. p. 103.

† Phil. Trans. No. 332.

produced at the same time, called "Black Island," being composed partly of brown trachyte. This volcano, now named Nea (or New) Kameni, continued in eruption, at intervals, during 1711 and 1712, and formed a cone 330 feet above the level of the sea: there are now, therefore, two channels of direct communication between the atmosphere and volcanic foci beneath the group of Santorin; namely, the craters of New and Little Kameni.

A curious fact is mentioned by M. Virlet, respecting the supposed slow and progressive rise of a solid ridge at the bottom of the sea. Twenty years ago there was a depth of fifteen fathoms water between the lesser Kameni and the port of Phira, in Santorin. In 1830, when MM. Virlet and Bory visited the spot, there was only a depth of between three and four fathoms; and they found that the bottom consisted of a hard rock, probably trachyte, measuring about eight hundred yards from E. to W., and five hundred only from N. to S. Beyond this the sea deepens rapidly on all sides. From these facts, and from information obtained on the spot, M. Virlet infers that the bed of the sea is rising gradually, and that, in all probability, a new island may one day appear, without commotion, above the surface. He suggests that the solid crust of rock now slowly rising may resemble a cork carried up by the fermentation of the liquor on which it floats.*

After the descriptions above given, we shall naturally be led to compare the three exterior islands which encircle the Gulf of Santorin to the semicircular escarpment of Somma, while the smaller islets thrown up since the historical era, in the centre of the gulf, may

* See M. Virlet's Memoir, before cited.

be likened to the modern cone, or rather cones, of Vesuvius.

Von Buch supposes that a solid dome of trachyte is now rising in the centre of the bay, and that the expansive force from below will, one day, burst an opening, and cause the uplifted rocks to dip on all sides from within outwards.* Undoubtedly the porous mass of white punice upheaved in 1707 (see p. 282.) implies the partial elevation of solid matter, and may be compared perhaps to the solid crust of scoriæ, which is often capable of supporting heavy weights on the surface of lava-currents still in motion. But such data are far too scanty and obscure to enable us to speculate with profit on the connection of the causes which may now be uplifting the bed of the sea in the place above mentioned, and those processes by which the more ancient volcanic rocks of Santorin acquired their present configuration.

It is naturally objected by M. Virlet, that if a mass like Santorin, which, including its submarine foundations, must be from 1700 to 2000 feet in thickness, was suddenly and violently heaved up from a horizontal position, we might expect to find the rocks traversed every where by rents which would diverge from the principal centre of movement to the circumference of the circular area. But these rents are wanting, as are all signs of the shattering and dislocation of the mass. At the same time he adduces a fact which seems conclusive against the notion, that the three exterior islands owe their peculiar structure to the upheaval of horizontal beds into a conical form. In examining the various currents of lava (the existence of which was unknown to Von Buch, who had

* Poggendorf's Annalen, 1836, p. 183.

not visited Santorin), it was found that the vesicles, or pores which abound in them, are lengthened in the several directions in which they would naturally be drawn out, if the melted matter had flowed towards different points of the compass from the summit of a conical mountain, of which the present islands were the base. The force of this argument will be appreciated by those who are aware that bubbles of confined gas in a fluid in motion assume an oval form, and that the direction of the longer axis coincides always with that of the stream. It is also observed by M. Virlet, that the deep stratum of white tufaceous conglomerate by which all the islands are uniformly covered, may well be supposed to have resulted from heavy showers of ejected matter which fell during that paroxysmal explosion, by which the great cone was originally blown up, truncated, and emptied in its interior.

The manner in which the external walls were separated into three distinct islands is easily conceived. The principal breaches are to the N. W., the quarter most exposed to the waves and currents. On this side, the earthquake of 236 b. c., mentioned by Pliny, may have caused a fissure, which allowed the waves and currents to penetrate and sweep away the incoherent tuffs and conglomerates, just as they washed away Graham Island; and if there happened to be little or no lava at certain points, the waves would in such places readily force a passage.*

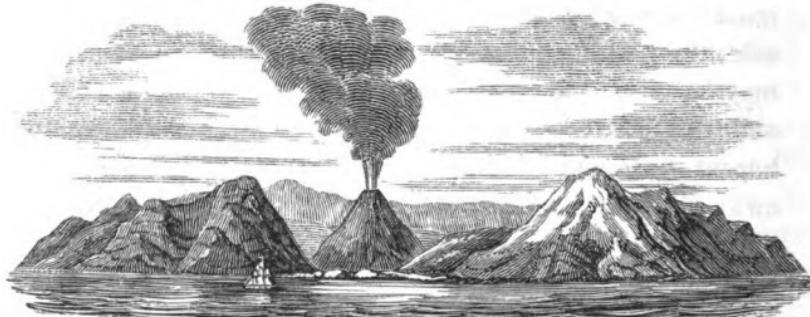
The dimensions of the Gulf of Santorin are not greater than we may suppose to result from the truncation and falling in of large volcanic cones. We shall afterwards see that Papandayang, formerly one

* Virlet, *ibid.*

of the loftiest volcanos in Java, lost, in 1772, about four thousand feet of its former height.* During an eruption in 1444, accompanied by a tremendous earthquake, the summit of Etna was destroyed, and an enormous crater was left, from which lava flowed. The segment of that crater may still be seen near the Casa Inglese, and, when complete, it must have measured several miles in diameter. If Etna had again been truncated down to the upper margin of the woody region, a circular basin would thus have been formed, thirty Italian miles in circumference, exceeding by five or six miles the circuit of the Gulf of Santorin. Yet we have every reason to believe that the beds of felspathic and basaltic lavas, with the alternating tuffs and breccias, would, in that part of the great cone of Etna, dip on all sides off from the centre, at angles of from about 15° to 30° , to every point of the compass.

Barren Island. — There is great analogy between the structure of Barren Island in the Bay of Bengal,

Fig. 49.

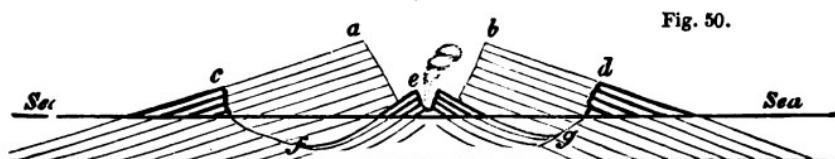


Cone and Crater of Barren Island, in the Bay of Bengal. — Height of the central cone 1848 feet. (Von Buch.)

lat. $12^{\circ} 15'$., and that of Santorin last described. When seen from the ocean, this island presents, on almost

* See chap. xvii.

all sides, a surface of bare rocks, rising, with a moderate acclivity, towards the interior; but at one point there is a cleft, by which we can penetrate into the centre, and there discover that it is occupied by a great circular basin, filled by the waters of the sea, and bordered all around by steep rocks, in the midst of which rises a volcanic cone, very frequently in eruption. The summit of this cone is 1848 feet in height, corresponding to that of the circular border which incloses the basin; so that it can be seen from the sea only through the ravine. It is most probable that the exterior inclosure of Barren Island, *c*, *d* (Fig. 50.), is nothing more than the remains of a truncated cone, *c*, *a*, *b*, *d*, a great portion of which has been removed by engulfments, or by explosions which preceded the formation of the new interior cone *f*, *e*, *g*.



Supposed section of Barren Island, in the Bay of Bengal.

Mineral composition of volcanic products. — The mineral called felspar forms in general more than half of the mass of modern lavas. When it is in great excess, lavas are called trachytic; they consist generally of a base of compact felspar, in which crystals of glassy felspar are disseminated.* When augite (or pyroxene) predominates, lavas are termed basaltic. But others of an intermediate composition occur, which from their colour have been called gray-stones. The

* See Glossary.

abundance of quartz, forming distinct crystals or concretions, characterizes the granitic and other ancient rocks, now generally considered by geologists as of igneous origin : whereas that mineral is rarely exhibited in a separate form in recent lavas, although silica enters largely into their composition. Hornblende, so common in hypogene rocks, or those commonly called "primary," is rare in modern lava ; nor does it enter largely into rocks of any age in which augite abounds. It should, however, be stated, that the experiments of M. Gustavus Rose have made it very questionable, whether the minerals called hornblende and augite can be separated as distinct species, as their different varieties seem to pass into each other, whether we consider the characters derived from their angles of crystallization, their chemical composition, or their specific gravity. The difference in form of the two substances may be explained by the different circumstances under which they have been produced ; the form of hornblende being the result of slower cooling. Crystals of augite have been met with in the scoriæ of furnaces, but never those of hornblende ; and crystals of augite have been obtained by melting hornblende in a platina crucible, but hornblende itself has not been formed artificially.* Mica occurs plentifully in some recent trachytes, but is rarely present where augite is in excess.

Frequency of eruptions, and nature of subterranean igneous rocks. — When we speak of the igneous rocks of our own times, we mean that small portion which, in violent eruptions, is forced up by elastic fluids to the surface of the earth, — the sand, scoriæ, and lava, which cool in the open air. But we cannot obtain ac-

* Bulletin de la Soc. Géol. de France, tom. ii. p. 206.

cess to that which is congealed far beneath the surface under great pressure, equal to that of many hundred, or many thousand atmospheres.

During the last century, about fifty eruptions are recorded of the five European volcanic districts, of Vesuvius, Etna, Volcano, Santorin, and Iceland; but many beneath the sea in the Grecian archipelago and near Iceland may doubtless have passed unnoticed. If some of them produced no lava, others, on the contrary, like that of Skaptár Jokul, in 1783, poured out melted matter for five or six years consecutively; which cases, being reckoned as single eruptions, will compensate for those of inferior strength. Now, if we consider the active volcanos of Europe to constitute about a fortieth part of those already known on the globe, and calculate that, one with another, they are about equal in activity to the burning mountains in other districts, we may then compute that there happen on the earth about 2000 eruptions in the course of a century, or about twenty every year.

However inconsiderable, therefore, may be the superficial rocks which the operations of fire produce on the surface, we must suppose the subterranean changes now constantly in progress to be on the grandest scale. The loftiest volcanic cones must be as insignificant, when contrasted to the products of fire in the nether regions, as are the deposits formed in shallow estuaries when compared to submarine formations accumulating in the abysses of the ocean. In regard to the characters of these volcanic rocks, formed in our own times in the bowels of the earth, whether in rents and caverns, or by the cooling of lakes of melted lava, we may safely infer that the rocks are heavier and less porous than ordinary lavas, and more crystalline,

although composed of the same mineral ingredients. As the hardest crystals produced artificially in the laboratory require the longest time for their formation, so we must suppose that where the cooling down of melted matter takes place by insensible degrees, in the course of ages, a variety of minerals will be produced far harder than any formed by natural processes within the short period of human observation.

These subterranean volcanic rocks, moreover, cannot be stratified in the same manner as sedimentary deposits from water, although it is evident that when great masses consolidate from a state of fusion, they may separate into natural divisions ; for this is seen to be the case in many lava-currents. We may also expect that the rocks in question will often be rent by earthquakes, since these are common in volcanic regions ; and the fissures will be often injected with similar matter, so that dikes of crystalline rock will traverse masses of similar composition. It is also clear, that no organic remains can be included in such masses, as also that these deep-seated igneous formations considered in mass must underlie all the strata containing organic remains, because the heat proceeds from below upwards, and the intensity required to reduce the mineral ingredients to a fluid state must destroy all organic bodies in rocks included in the midst of them.

If by a continued series of elevatory movements, such masses shall hereafter be brought up to the surface, in the same manner as sedimentary marine strata have, in the course of ages, been upheaved to the summit of the loftiest mountains, it is not difficult to foresee what perplexing problems may be presented to the geologist. He may then, perhaps, study in some

mountain chain the very rocks produced at the depth of several miles beneath the Andes, Iceland, or Java, in the time of Leibnitz, and draw from them the same conclusion which that philosopher derived from certain igneous products of high antiquity; for he conceived our globe to have been, for an indefinite period, in the state of a comet, without an ocean, and uninhabitable alike by aquatic or terrestrial animals.

CHAPTER XV.

EARTHQUAKES AND THEIR EFFECTS.

Earthquakes and their effects — Deficiency of ancient accounts — Ordinary atmospheric phenomena — Changes produced by earthquakes in modern times considered in chronological order — Earthquake in Syria, 1837 — Earthquakes in Chili in 1837 and 1835 — Isle of Santa Maria raised ten feet — Chili, 1822 — Extent of country elevated — Aleppo and Ionian Isles — Earthquake of Cutch in 1819 — Subsidence in the Delta of the Indus — Island of Sumbawa in 1815 — Town of Tomboro submerged — Earthquake of Caraccas in 1812 — New Madrid in 1811 — Changes in the valley of the Mississippi — Aleutian Islands in 1806 — Reflections on the earthquakes of the nineteenth century — Earthquake in Quito, Quebec, &c. — Java, 1786 — Sinking down of large tracts — Japan Isles, 1783.

In the sketch before given of the geographical boundaries of volcanic regions, I stated, that although the points of eruption are but thinly scattered, constituting mere spots on the surface of those vast districts, yet the subterranean movements extend simultaneously over immense areas. We may now proceed to consider the changes which these movements produce on the surface, and in the internal structure of the earth's crust.

Deficiency of ancient accounts. — It is only within the last century and a half since Hooke first promulgated his views respecting the connection between geological phenomena and earthquakes, that the per-

manent changes effected by these convulsions have excited attention. Before that time, the narrative of the historian was almost exclusively confined to the number of human beings who perished; the number of cities laid in ruins, the value of property destroyed, or certain atmospheric appearances which dazzled or terrified the observers. The creation of a new lake, the engulfing of a city, or the raising of a new island, are sometimes, it is true, adverted to, as being too obvious, or of too much geographical or political interest, to be passed over in silence. But no researches were made expressly with a view of ascertaining the amount of depression or elevation of the ground, or any particular alterations in the relative position of sea and land; and very little distinction was made between the raising of soil by volcanic ejections, and the upheaving of it by forces acting from below. The same remark applies to a very large proportion of modern accounts; and how much reason we have to regret this deficiency of information appears from this, that in every instance where a spirit of scientific inquiry has animated the eye-witnesses of these events, facts calculated to throw light on former modifications of the earth's structure are recorded.

Phenomena attending earthquakes. — As I shall confine myself almost entirely, in the following notice of earthquakes, to the changes brought about by them in the configuration of the earth's crust, I may mention, generally, some accompaniments of these terrible events which are almost uniformly commemorated in history, that it may be unnecessary to advert to them again. Irregularities in the seasons preceding or following the shocks; sudden gusts of wind, interrupted by dead calms; violent rains at unusual seasons, or in

countries where such phenomena are almost unknown ; a reddening of the sun's disk, and a haziness in the air, often continued for months ; an evolution of electric matter, or of inflammable gas from the soil, with sulphurous and mephitic vapours ; noises underground, like the running of carriages, or the discharge of artillery, or distant thunder ; animals uttering cries of distress, and evincing extraordinary alarm, being more sensitive than men of the slightest movement ; a sensation like sea-sickness, and a dizziness in the head, experienced by men :—these, and other phenomena, which are still more remotely connected with our present subject as geologists, have recurred again and again at distant ages, and in all parts of the globe.

I shall now begin the enumeration of earthquakes with the latest authentic narratives, and so carry back the survey retrospectively, that I may bring before the reader, in the first place, the minute and circumstantial details of modern times, and thus enable him, by observing the extraordinary amount of change within the last 150 years, to perceive how great must be the deficiency in the meagre annals of earlier eras.

EARTHQUAKES OF THE NINETEENTH CENTURY.*

Syria, January, 1837. — It has been remarked that earthquakes affect elongated areas. The violent shock

* Since the publication of the first edition of this work, numerous accounts of recent earthquakes have been published ; but as they do not illustrate any new principle, I cannot insert them all, as they would enlarge too much the size of my work. Among the most violent may be mentioned those of March, 1829, near Alicant in Murcia — that of Sept. 1827, at Lahore, East Indies

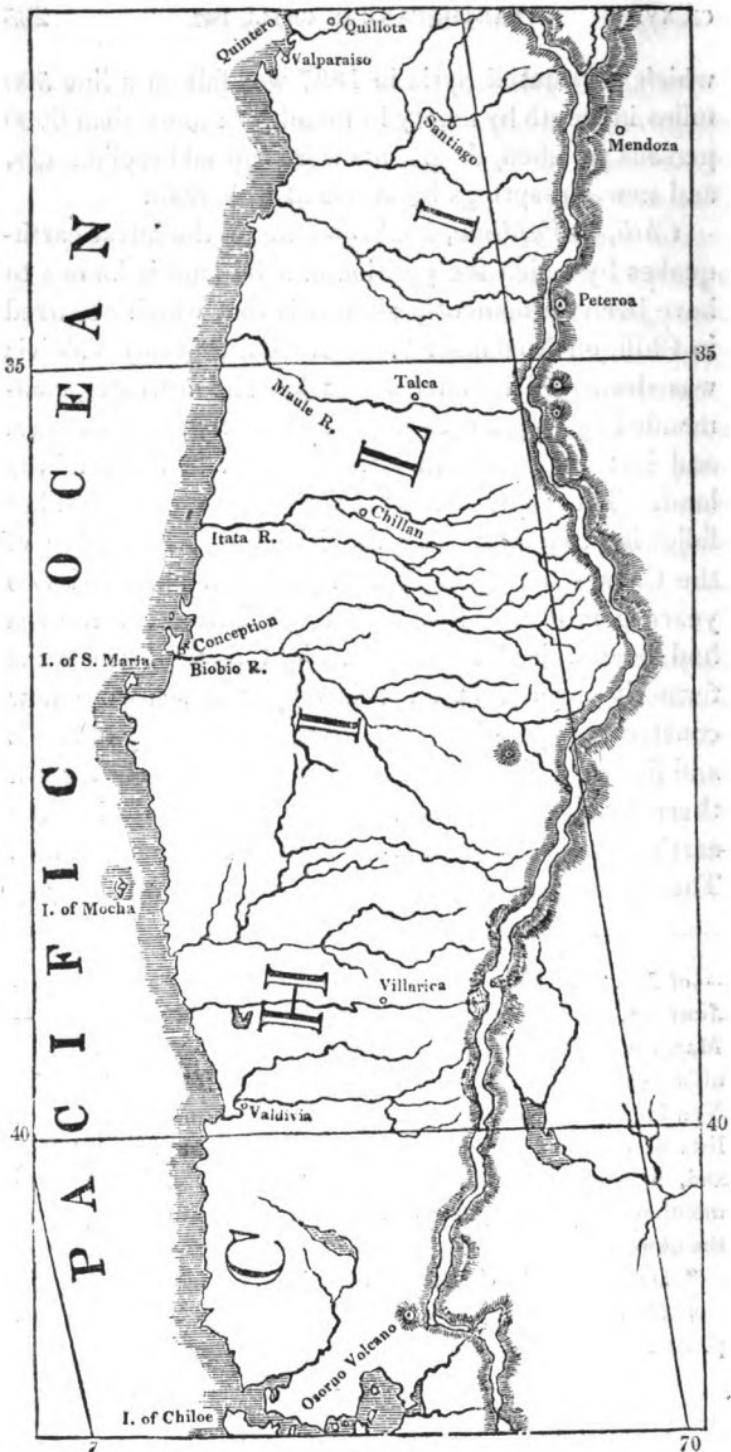
which devastated Syria in 1837 was felt on a line 500 miles in length by ninety in breadth * : more than 6000 persons perished, deep rents were caused in solid rocks, and new hot springs burst out at Tabereah.

Chili, — Valdivia, 1837. — One of the latest earthquakes by which the position of solid land is known to have been permanently altered is that which occurred in Chili, on November 7. 1837. On that day Valdivia was destroyed by an earthquake, and a whaler, commanded by Captain Coste, was violently shaken at sea, and lost her masts, in lat. $43^{\circ} 38'$ S. in sight of the land. The captain went on the 11th of December following to a spot near the island of Lemus, one of the Chonos archipelago, where he had anchored two years before, and found that the bottom of the sea had been raised more than eight feet. Some rocks formerly covered at all times by the sea were now constantly exposed, and an enormous quantity of shells and fish in a decaying state, which had been thrown there by the waves, or suddenly laid dry during the earthquake, attested the recent date of the occurrence. The whole coast was strewed with uprooted trees.†

— of Jan. 15. 1832, which almost destroyed Foligno, in Italy — June 24. 1830, in China, in Tayming, North of Houan — March 9. 1830, in the Caucasus at Kislier — April 1833, Manila — 1833, Isle of Lissa in Adriatic, and Opus. The late Von Hoff published, from time to time, in Poggendorf's Annalen, lists of earthquakes which happened between 1821 and 1836; and, by consulting these, the reader will perceive that every month is signalized by one or many convulsions in some part of the globe.

* Darwin, Geol. Proceedings, vol. ii. p. 658.

† Dumoulin, Comptes Rendus de l'Acad. des Sci., Oct. 1838, p. 706.



Chili — Conception, 1835. — Fortunately we have a still more detailed account of the geographical changes produced in the same country on the 20th of February, 1835. An earthquake was then felt at all places between Copiapo and Chiloe, from north to south, and from Mendoza to Juan Fernandez, from east to west. "Vessels," says Mr. Caldcleugh, "navigating the Pacific, within 100 miles of the coast, experienced the shock with considerable force."* Conception, Talcahuano, Chillan, and other towns were thrown down. From the account of Captain Fitz Roy, R.N., who was then employed in surveying the coast, we learn that after the shock the sea retired in the Bay of Conception, and the vessels grounded, even those which had been lying in seven fathoms water; all the shoals were visible, and soon afterwards a wave rushed in and then retreated, and was followed by two other waves. The vertical height of these waves does not appear to have been much greater than from sixteen to twenty feet, although they rose to much greater heights when they broke upon a sloping beach.

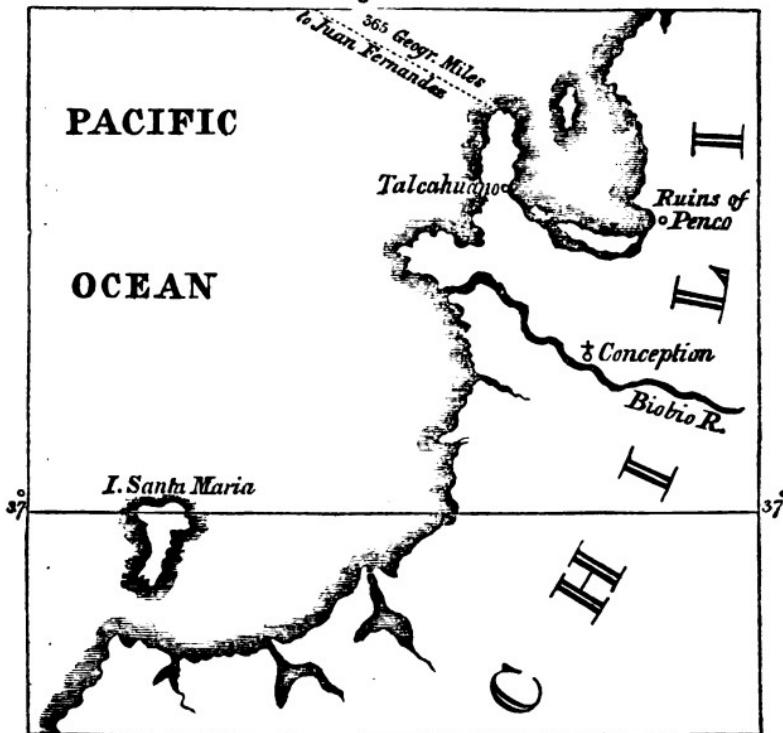
According to Mr. Caldcleugh and Mr. Darwin, the whole volcanic chain of the Chilian Andes, a range 150 miles in length, was in a state of unusual activity, both during the shocks and for some time preceding and after the convulsion, and lava was seen to flow from the crater of Osorno. (See Map, fig. 51.) The island of Juan Fernandez, distant 365 geographical miles from Chili, was violently shaken at the same time, and devastated by a great wave. A submarine volcano broke out there near Bacalao Head, about a mile from the shore, in sixty-nine fathoms water, and illuminated the whole island during the night.†

* Phil. Trans. 1836, p. 21.

† Ibid. p. 25.

"At Conception," says Captain Fitz Roy, "the earth opened and closed rapidly in numerous places. The direction of the cracks was not uniform, though generally from south-east to north-west. The earth was not quiet for three days after the great shock, and more than 300 shocks were counted between the 20th February and the 4th of March. The loose earth of the valley of the Biobio was everywhere parted from the solid rocks which bound the plain, there being an opening between them from an inch to a foot in width.

Fig. 52.



"For some days after the 20th of February, the sea at Talcahuano," says Captain Fitz Roy, "did not rise to

the usual marks by four or five feet vertically. When walking on the shore, even at high water, beds of dead mussels, numerous chitons, and limpets, and withered sea-weed, still adhering, though lifeless, to the rocks on which they had lived, everywhere met the eye." But this difference in the relative level of the land and sea gradually diminished, till in the middle of April the water rose again to within two feet of the former high water mark. It might be supposed that these changes of level merely indicated a temporary disturbance in the set of the currents or in the height of the tides at Talcahuano; but, on considering what occurred in the neighbouring island of Santa Maria, Captain Fitz Roy concluded that the land had been raised four or five feet in February, and that it had returned in April to within two or three feet of its former level.

Santa Maria, the island just alluded to, is about seven miles long and two broad, and about twenty-five miles south-west of Conception. (See Map, fig. 52.) The phenomena observed there are most important. "It appeared," says Captain Fitz Roy, who visited Santa Maria twice, the first time at the end of March, and afterwards in the beginning of April, "that the southern extremity of the island had been raised eight feet, the middle nine, and the northern end upwards of ten feet. On steep rocks, where vertical measures could be correctly taken, beds of dead mussels were found ten feet above high water mark. One foot lower than the highest bed of mussels, a few limpets and chitons were seen adhering to the rock where they had grown. Two feet lower than the same, dead mussels, chitons, and limpets were abundant.

"An extensive rocky flat lies around the northern parts of Santa Maria. Before the earthquake this flat

was covered by the sea, some projecting rocks only showing themselves. Now, the whole flat is exposed, and square acres of it are covered with dead shell-fish, the stench arising from which is abominable. By this elevation of the land the southern port of Santa Maria has been almost destroyed; little shelter remaining there, and very bad landing." The surrounding sea is also stated to have become shallower in exactly the same proportion as the land had risen; the soundings having diminished a fathom and a half everywhere around the island.

At Tubal, also, to the south-east of Santa Maria, the land was raised six feet, at Mocha two feet, but no elevation could be ascertained at Valdivia.

Among other effects of the catastrophe it is stated, that cattle standing on a steep slope, near the shore, were rolled down into the sea, and many others were washed off by the great wave from low land and drowned.*

In November of the same year (1835), Conception was shaken by a severe earthquake, and on the same day Osorno, at the distance of 400 miles, renewed its activity. These facts prove not only the connection of earthquakes with volcanic eruptions in this region, but also the vast extent of the subterranean areas, over which the disturbing cause acts simultaneously.

Ischia, 1828. — On the 2nd of February the whole island of Ischia was shaken by an earthquake, and in the October following I found all the houses in Casamicciol still without their roofs. On the sides of a ravine between that town and Forio, I saw masses of greenish tuff, which had been thrown down. The hot-

* Darwin's Journ. of Travels in South America, in voyage of H. M. ship Beagle, p. 372.

spring of Rita, which was nearest the centre of the movement, was ascertained by M. Covelli to have increased in temperature, showing, as he observes, that the explosion took place below the reservoirs which heat the thermal waters.*

Bogota, 1827.—On the 16th of November, 1827, the plain of Bogota, in New Granada, or Colombia, was convulsed by an earthquake, and a great number of towns were thrown down. Torrents of rain swelled the Magdalena, sweeping along vast quantities of mud and other substances, which emitted a sulphurous vapour and destroyed the fish. Popayan, which is distant two hundred geographical miles S.S.W. of Bogota, suffered greatly. Wide crevices appeared in the road of Guanacas, leaving no doubt that the whole of the Cordilleras sustained a powerful shock. Other fissures opened near Costa, in the plains of Bogota, into which the river Tunza immediately began to flow.† It is worthy of remark, that in all such cases the ancient gravel bed of a river is deserted, and a new one formed at a lower level; so that a want of relation in the position of alluvial beds to the existing water-courses may be no test of the high antiquity of such deposits, at least in countries habitually convulsed by earthquakes. Extraordinary rains accompanied the shocks before mentioned; and two volcanos are said to have been in eruption in the mountain-chain nearest to Bogota.

Chili, 1822.—On the 19th of November, 1822, the coast of Chili was visited by a most destructive earthquake. The shock was felt simultaneously throughout a space of 1200 miles from north to south. St. Jago,

* Biblioth. Univ. Oct. 1828, p. 157.; and Féruſſac, Bulletin, &c., tome xi. p. 227.

† Phil. Mag. July, 1828, p. 37.

Valparaiso, and some other places, were greatly injured. When the district round Valparaiso was examined on the morning after the shock, it was found that the coast, for a considerable distance, was raised above its former level.* At Valparaiso the elevation was three feet, and at Quintero about four feet. Part of the bed of the sea, says Mrs. Graham, remained bare and dry at high water, "with beds of oysters, mussels, and other shells adhering to the rocks on which they grew, the fish being all dead, and exhaling most offensive effluvia."†

An old wreck of a ship, which before could not be approached, became accessible from the land, although its distance from the original sea-shore had not altered.‡ It was observed, that the water-course of a mill, at the distance of about a mile from the sea, gained a fall of fourteen inches, in little more than one hundred yards; and from this fact it is inferred that the rise in some parts of the inland country was far more considerable than on the borders of the ocean.§ Part of the coast thus elevated consisted of granite, in which parallel fissures were caused, some of which were traced for a mile and a half inland. Cones of earth, about four feet high, were thrown up in several districts, by the forcing up of water mixed with sand through funnel-shaped hollows,—a phenomenon very common in Calabria, and the explanation of which will hereafter be considered. Those houses in Chili of which the foundations were on rock were less damaged than such as were built on alluvial soil.

* See Geol. Trans. vol. i., second series; and also Journ. of Sci. 1824, vol. xvii. p. 40.

† Geol. Trans., vol. i., second series, p. 415.

‡ Ibid.

§ Journ. of Sci. vol. xvii. p. 42.

Mr. Cruckshanks, an English botanist, who resided in the country during the earthquake, has informed me that some rocks of greenstone at Quintero, a few hundred yards from the beach, which had always been under water till the shock of 1822, have since been uncovered when the tide is at half-ebb; and he states that, after the earthquake, it was the general belief of the fishermen and inhabitants of the Chilian coast, *not* that the land had risen, but that the ocean had permanently retreated.

Dr. Meyen, a Prussian traveller, who visited Valparaiso in 1831, says that on examining the rocks both north and south of the town, nine years after the event, he found, in corroboration of Mrs. Graham's account, that remains of animals and sea-weed, the *Lessonia* of Bory de St. Vincent, which has a firm ligneous stem, still adhered to those rocks which in 1822 had been elevated above high water mark.* According to the same author, the whole coast of Central Chili was raised about four feet, and banks of marine shells were laid dry on many parts of the coast. He observed similar banks, elevated at unknown periods, in several places, especially at Copiapo, where the species all agree with those now living in the ocean. Mr. Freyer also, who resided some years in South America, has confirmed these statements †; but Mr. Cuming, a gentleman well known by his numerous discoveries in conchology, and who resided at Valparaiso during and after the earthquake, could detect no proofs of the rise of the land, nor any signs of a change of level. On the contrary, he states, that

* Reise um die erde; and see Dr. Meyen's letter cited Foreign Quart. Rev. No. 38. p. 13. 1836.

† Geol. Soc. Proceedings, No. 40. p. 179., Feb. 1835.

the water at spring tides rose after the earthquake to the same point on a wall near his house, which it had reached before the shocks.* On the other hand, Mr. Darwin obtained evidence that the remains of an ancient wall, formerly washed by the sea, and now 11½ feet above high water mark, acquired several feet of this additional elevation during the earthquake of 1822.†

The shocks continued up to the end of September, 1823; even then, forty-eight hours seldom passed without one, and sometimes two or three were felt during twenty-four hours. Mrs. Graham observed, after the earthquake of 1822, that, besides a beach newly raised above high water mark, there were several older elevated lines of beach one above the other, consisting of shingle mixed with shells, extending in a parallel direction to the shore, to the height of fifty feet above the sea.‡

Extent of country elevated. — By some observers it has been supposed that the whole country from the foot of the Andes to a great distance under the sea was upraised in 1822, the greatest rise being at the distance of about two miles from the shore. "The rise upon the coast was from two to four feet: — at the distance of a mile inland it must have been from five to six, or seven feet." § It has also been conjectured by the same eye-witnesses to the convulsion, that the area over which this permanent alteration of level extended may have been equal to 100,000 square miles. Although the increased fall of certain

* Cuming, Geol. Proceedings, No. 42. p. 213.

† Proceedings Geol. Soc. vol. ii. p. 447.

‡ Geol. Trans. vol. i., second series, p. 415.

§ Journal of Sci. vol. xvii. pp. 40. 45.

water-courses may have afforded some ground for this conjecture, it must be considered as very hypothetical, and the estimate may have exceeded or greatly fallen short of the truth. It may nevertheless be useful to reflect on the enormous amount of change which this single convulsion occasioned, if the extent of country moved upward really amounted to 100,000 square miles,—an extent just equal to half the area of France, or about five-sixths of the area of Great Britain and Ireland. If we suppose the elevation to have been only three feet on an average, it will be seen that the mass of rock added to the continent of America by the movement, or, in other words, the mass previously below the level of the sea, and after the shocks permanently above it, must have contained fifty-seven cubic miles in bulk; which would be sufficient to form a conical mountain two miles high (or about as high as Etna), with a circumference at the base of nearly thirty-three miles. We may take the mean specific gravity of the rock at 2·655,—a fair average, and a convenient one in such computations, because at such a rate a cubic yard weighs two tons. Then, assuming the great pyramid of Egypt, if solid, to weigh, in accordance with an estimate before given, six million tons, we may state the rock added to the continent by the Chilian earthquake to have more than equalled 100,000 pyramids.

But it must always be borne in mind that the weight of rock here alluded to constituted but an insignificant part of the whole amount which the volcanic forces had to overcome. The whole thickness of rock between the surface of Chili and the subterranean foci of volcanic action may be many miles or leagues deep. Say that the thickness was only two miles, even then

the mass which changed place and rose three feet being 200,000 cubic miles in volume, must have exceeded in weight 363 million pyramids.

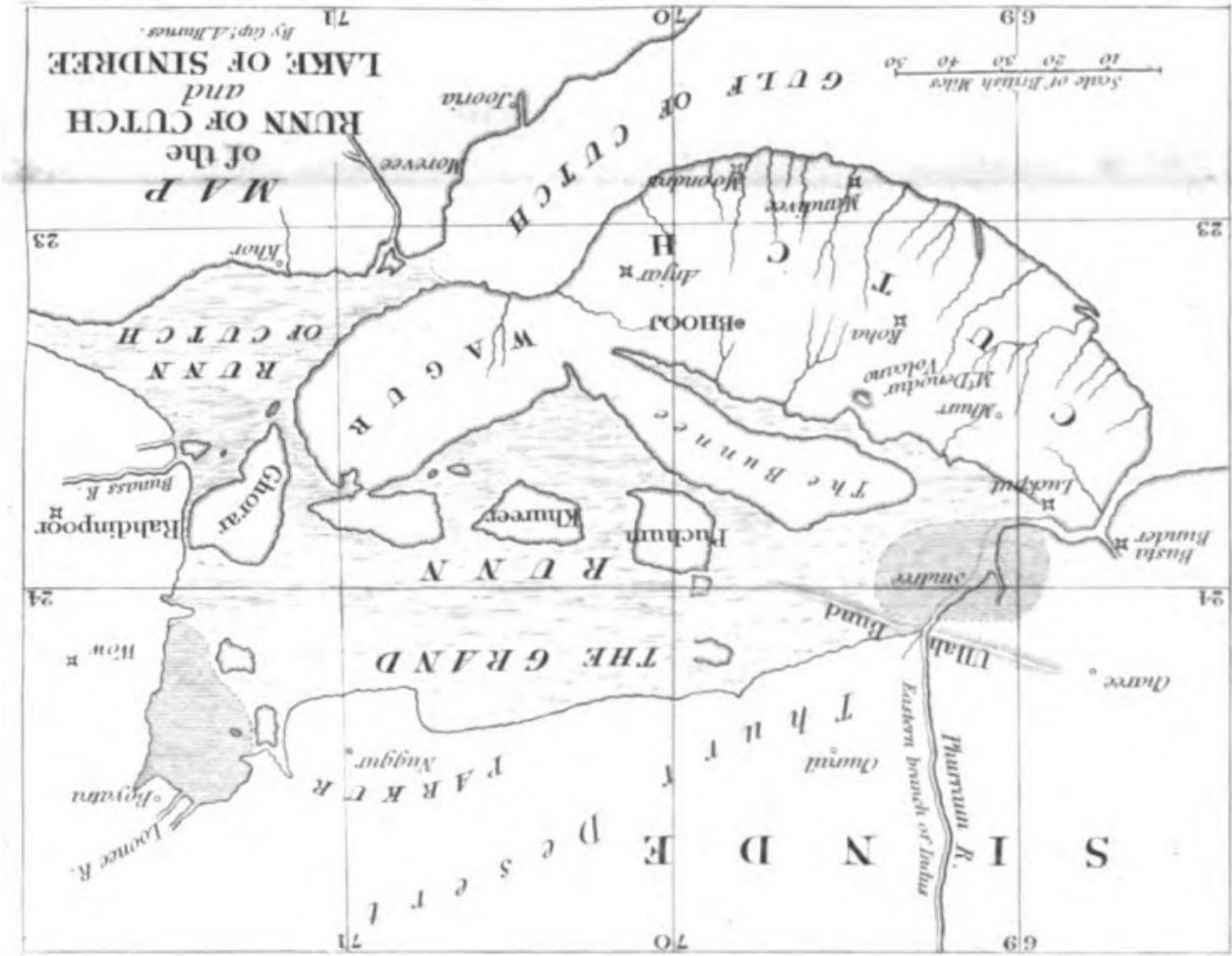
It may be instructive to consider these results in connection with others already obtained from a different source, and to compare the working of two antagonist forces — the levelling power of running water, and the expansive energy of subterranean heat. How long, it may be asked, would the Ganges require, according to data before explained, to transport to the sea a quantity of solid matter equal to that which may have been added to the land by the Chilian earthquake? The discharge of mud in one year by the Ganges equalled the weight of sixty pyramids. In that case it would require seventeen centuries and a half before the river could bear down from the continent into the sea a mass equal to that gained by the Chilian earthquake. In about half that number of centuries, perhaps, the united waters of the Ganges and Burrampooter might accomplish the operation.

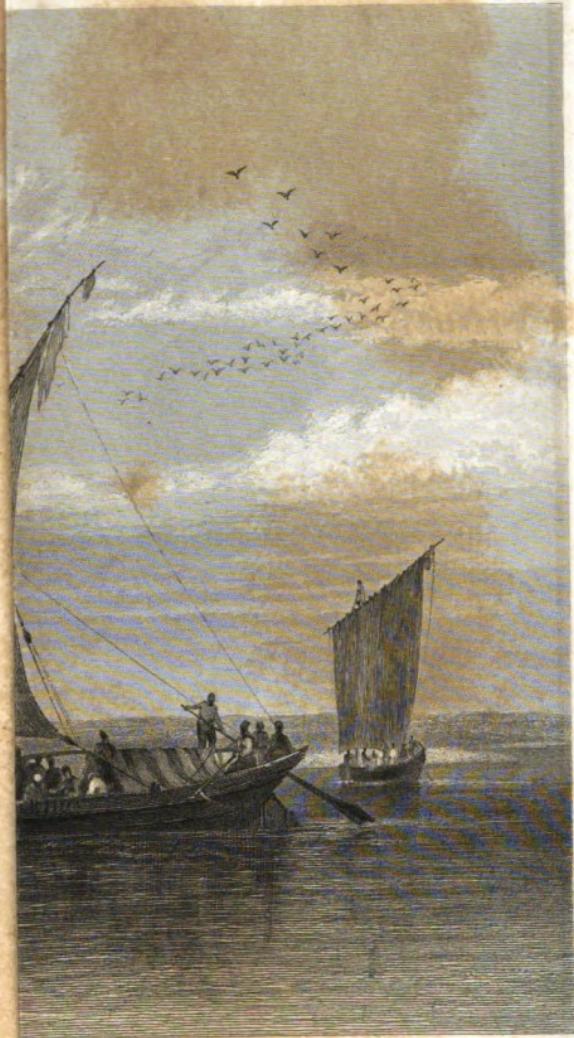
Aleppo, 1822. — Ionian Isles, 1820. — When Aleppo was destroyed by an earthquake in 1822, two rocks are reported to have risen from the sea near the island of Cyprus *; and a new rocky island was observed in 1820, not far from the coast of Santa Maura, one of the Ionian Islands, after violent earthquakes.†

Cutch, 1819. — A violent earthquake occurred at Cutch, in the delta of the Indus, on the 16th of June, 1819. (See Map, plate 10.) The principal town, Bhooj, was converted into a heap of ruins, and its stone buildings were thrown down. The shock extended to Ahmedabad, where it was very destructive;

* Journ. of Sci. vol. xiv. p. 450.

† Von Hoff, vol. ii. p. 180.





Engraved by E. Finden.

the Indus.

9.

1808.

Street.

and at Poonah, four hundred miles farther, it was feebly felt. At the former city, the great mosque erected by Sultan Ahmed nearly 450 years before, fell to the ground, attesting how long a period had elapsed since a shock of similar violence had visited that point. At Anjar, the fort, with its tower and guns, were hurled to the ground in one common mass of ruin. The shocks continued some days until the 20th ; when, thirty miles north-west from Bhooj, the volcano called Denodur is said to have burst out in eruption, and the convulsions ceased.

Subsidence in the delta of the Indus. — Although the ruin of towns was great, the face of nature in the inland country, says Captain Macmurdo, was not visibly altered. In the hills some large masses only of rock and soil were detached from the precipices ; but the eastern and almost deserted channel of the Indus, which bounds the province of Cutch, was greatly changed. This estuary, or inlet of the sea, was, before the earthquake, fordable at Luckput, being only about a foot deep when the tide was at ebb, and at flood tide never more than six feet ; but it was deepened at the fort of Luckput, after the shock, to more than eighteen feet at low water.* On sounding other parts of the channel, it was found, that where previously the depth of the water at flood never exceeded one or two feet, it had become from four to ten feet deep. By these and other remarkable changes of level, a part of the inland navigation of that country, which had been closed for centuries, became again practicable.

Fort and village submerged. † — The fort and village

* Macmurdo, Ed. Phil. Journ. vol. iv. p. 106.

† I am indebted to Captain (now Col. Sir A.) Burnes for the accompanying engraving (Plate XI.) of the Fort of Sindree,

of Sindree, on the eastern arm of the Indus, above Luckput, are stated by the same writer to have been overflowed; and, after the shock, the tops of the houses and wall were alone so be seen above the water, for the houses, although submerged, were not cast down. Had they been situated, therefore, in the interior, where so many forts were levelled to the ground, their site would, perhaps, have been regarded as having remained comparatively unmoved. Hence we may suspect that great permanent upheavings and depressions of soil may be the result of earthquakes, without the inhabitants being in the least degree conscious of any change of level.

A more recent survey of Cutch by Capt. A. Burnes, who was not in communication with Capt. Macmurdo, confirms the facts above enumerated, and adds many important details.* That officer examined the delta of the Indus in 1826 and 1828, and from his account it appears that, when Sindree subsided in June, 1819, the sea flowed in by the eastern mouth of the Indus, and in a few hours converted a tract of land, 2000 square miles in area, into an inland sea, or lagoon. Neither the rush of the sea into this new depression, nor the movement of the earthquake, threw down entirely the small fort of Sindree, one of the four

as it appeared eleven years before the earthquake ; but I am assured by Captain Grant, and others well acquainted with the scene, that the land introduced by the artist in the back-ground is ideal. The flat plain of the Runn could alone be seen in that direction as far as the eye can reach. The mirage so common there may have caused the apparent inequalities which have been introduced as rising ground into the sketch.

* This Memoir is now in the Library of the Royal Asiatic Society of London.

towers, the north-western, still continuing to stand ; and the day after the earthquake, the inhabitants, who had ascended to the top of this tower, saved themselves in boats.*

Elevation of the Ullah Bund. — Immediately after the shock, the inhabitants of Sindree saw, at the distance of five miles and a half from their village, a long elevated mound, where previously there had been a low and perfectly level plain. (See Map, pl. 10.) To this uplifted tract they gave the name of "Ullah Bund," or the "Mound of God," to distinguish it from several artificial dams previously thrown across the eastern arm of the Indus.

Extent of country raised. — It has been already ascertained that this new-raised country is *upwards of fifty miles* in length from east to west, running parallel to that line of subsidence before mentioned which caused the grounds around Sindree to be flooded. The range of this elevation extends from Puchum Island towards Gharee ; its breadth from north to south is conjectured to be in some parts *sixteen miles*, and its greatest ascertained height above the original level of the delta is ten feet, — an elevation which appears to the eye to be very uniform throughout.

For several years after the convulsion of 1819, the course of the Indus was very unsettled, and at length, in 1826, the river threw a vast body of water into its eastern arm, that called the Phurraun, above Sindree ; and forcing its way in a more direct course to the sea, burst through all the artificial dams which had been thrown across its channel, and at length cut right

* I have been enabled, from personal communication with Captain Burnes, to add several particulars to my former account of this earthquake.

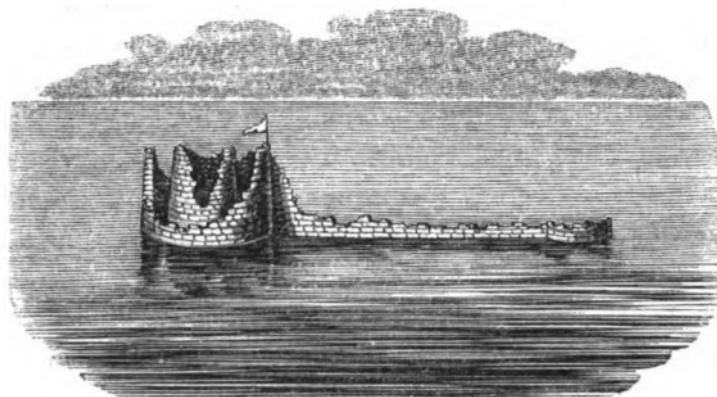
through the “Ullah Bund,” whereby a natural section was obtained. In the perpendicular cliffs thus laid open, Captain Burnes found that the upraised lands consisted of clay filled with shells. The new channel of the river where it intersected the “bund,” was eighteen feet deep, and forty yards in width; but in 1828 the channel was still further enlarged. The Indus, when it first opened this new passage, threw such a body of water into the new mere, or salt lagoon, of Sindree, that it became fresh for many months; but it had recovered its saltiness in 1828, when the supply of river-water was less copious, and finally it became more salt than the sea, in consequence, as the natives suggested to Captain Burnes, of the saline particles with which the “Runn of Cutch” is impregnated.

In 1828 Captain Burnes went in a boat to the ruins of Sindree, where a single remaining tower was seen in the midst of a wide expanse of sea. The tops of the ruined walls still rose two or three feet above the level of the water; and standing on one of these, he could behold nothing in the horizon but water, except in one direction, where a blue streak of land to the north indicated the Ullah Bund. This scene presents to the imagination a lively picture of the revolutions now in progress on the earth — a waste of waters where a few years before all was land, and the only land visible consisting of ground uplifted by a recent earthquake.

Ten years after the visit of Captain Burnes above alluded to, my friend, Captain Grant, F. G. S. of the Bombay Engineers, had the kindness to send at my request a native surveyor to make a plan of Sindree and Ullah Bund, in March, 1838. From his description it appears that, at that season, the driest of the

whole year, he found the channel traversing the Bund to be 100 yards wide, without water, and encrusted with salt. He was told that it has now only four or five feet of water in it after rains. The sides or banks were nearly perpendicular, and nine feet in height. The lagoon has diminished both in area and depth, and part near the fort was dry land. The annexed drawing, made by Captain Grant from the surveyor's plan,

Fig. 53.



View of the Fort of Sindree, from the west, in March, 1838.

shows the appearance of the fort in the midst of the lake, as seen in 1838 from the west, or from the same point as that from which Captain Grindley's sketch (See Plate XI.) was taken in 1808, before the earthquake.

The Runn of Cutch is a flat region of a very peculiar character, and no less than 7000 square miles in area: a greater superficial extent than Yorkshire, or about one fourth the area of Ireland. It is not a desert of moving sand, nor a marsh, but evidently the dried-up bed of an inland sea, which for a great part of every year has a hard and dry bottom uncovered by weeds or grass, and only supporting here and there

a few tamarisks. But during the monsoons, when the sea runs high, the salt-water driven up from the Gulf of Cutch and the creeks at Luckput overflows a large part of the Runn, especially after rains, when the soaked ground permits the sea-water to spread rapidly. The Runn is also liable to be overflowed occasionally in some parts by river-water: and it is remarkable that the only portion which was ever highly cultivated (that anciently called Sayra) is now permanently submerged. The surface of the Runn is sometimes encrusted with salt about an inch in depth, in consequence of the evaporation of the sea-water. Islands rise up in some parts of the waste, and the boundary lands form bays and promontories. The natives have various traditions respecting the former separation of Cutch and Sinde by a bay of the sea, and the drying up of the district called the Runn. But these tales, besides the usual uncertainty of oral tradition, are farther obscured by mythological fictions. The conversion of the Runn into land is chiefly ascribed to the miraculous powers of a Hindoo saint, by name Damorath (or Dhoorunnath), who had previously done penance for twelve years on the summit of Denodur hill. Captain Grant infers, on various grounds, that this saint flourished about the eleventh or twelfth century of our era. In proof of the drying up of the Runn, some towns far inland are still pointed out as having once been ancient ports. It has, moreover, been always said that ships were wrecked and engulfed by the great catastrophe; and in the jets of black muddy water thrown out of fissures in that region, in 1819, there were cast up numerous pieces of wrought iron and ship nails.* Cones of sand six or eight feet in

* Capt. Burnes's Account.

height were at the same time thrown up on these lands.*

We must not conclude without alluding to a *moral* phenomenon connected with this tremendous catastrophe, which we regard as highly deserving the attention of geologists. It is stated by Captain Burnes, that "these wonderful events passed *unheeded* by the inhabitants of Cutch;" for the region convulsed, though once fertile, had for a long period been reduced to sterility by want of irrigation, so that the natives were indifferent as to its fate. Now it is to this profound apathy which all but highly civilized nations feel, in regard to physical events not having an immediate influence on their worldly fortunes, that we must ascribe the extraordinary dearth of historical information concerning changes of the earth's surface, which modern observations show to be by no means of rare occurrence in the ordinary course of nature.

To the east of the line of this earthquake lies Oojain (called Ozene in the *Periplus Maris Erythr.*). Ruins of an ancient city are there found, a mile north of the present, buried in the earth to the depth of from fifteen to sixteen feet, which inhumation is known to have been the consequence of a tremendous catastrophe in the time of the Rajah Vicramaditya.†

Island of Sumbawa, 1815. — In April, 1815, one of the most frightful eruptions recorded in history occurred in the province of Tomboro, in the island of Sumbawa, about 200 miles from the eastern extremity of Java. In the April of the year preceding the volcano had been observed in a state of considerable activity,

* Capt. Macmurdo's Memoir, Ed. Phil. Journ. vol. iv. p. 106.

† Von Hoff, vol. ii. p. 454. ; for further particulars, see book iii. chap. xiii.

ashes having fallen upon the decks of vessels which sailed past the coast.* The eruption of 1815 began on the 5th of April, but was most violent on the 11th and 12th, and did not entirely cease till July. The sound of the explosions was heard in Sumatra, at the distance of 970 geographical miles in a direct line; and at Ternate, in an opposite direction, at the distance of 720 miles. Out of a population of 12,000, in the province of Tomboro, only twenty-six individuals survived. Violent whirlwinds carried up men, horses, cattle, and whatever else came within their influence, into the air; tore up the largest trees by the roots, and covered the whole sea with floating timber.† Great tracts of land were covered by lava, several streams of which, issuing from the crater of the Tomboro mountain, reached the sea. So heavy was the fall of ashes, that they broke into the Resident's house at Bima, forty miles east of the volcano, and rendered it, as well as many other dwellings in the town, uninhabitable. On the side of Java the ashes were carried to the distance of 300 miles, and 217 towards Celebes, in sufficient quantity to darken the air. The floating cinders to the westward of Sumatra formed, on the 12th of April, a mass two feet thick, and several miles in extent, through which ships with difficulty forced their way.

The darkness occasioned in the daytime by the ashes in Java was so profound, that nothing equal to it was ever witnessed in the darkest night. Although this volcanic dust when it fell was an impalpable powder, it was of considerable weight when compressed, a pint of it weighing twelve ounces and three quarters.

* MS. of J. Crawfurd, Esq.

† Raffles's Java, vol. i. p. 28.

"Some of the finest particles," says Mr. Crawfurd, "were transported to the islands of Amboyna and Banda, which last is about 800 miles east from the site of the volcano, although the south-east monsoon was then at its height." They must have been projected, therefore, into the upper regions of the atmosphere, where a counter current prevailed.

Along the sea-coast of Sumbawa, and the adjacent isles, the sea rose suddenly to the height of from two to twelve feet, a great wave rushing up the estuaries, and then suddenly subsiding. Although the wind at Bima was still during the whole time, the sea rolled in upon the shore, and filled the lower parts of the houses with water a foot deep. Every prow and boat was forced from the anchorage, and driven on shore.

The town called Tomboro, on the west side of Sumbawa, was overflowed by the sea, which encroached upon the shore so that the water remained permanently eighteen feet deep in places where there was land before. Here we may observe, that the amount of subsidence of land was apparent, in spite of the ashes, which would naturally have caused the limits of the coast to be extended.

The area over which tremulous noises and other volcanic effects extended, was 1000 English miles in circumference, including the whole of the Molucca Islands, Java, a considerable portion of Celebes, Sumatra, and Borneo. In the island of Amboyna, in the same month and year, the ground opened, threw out water, and then closed again.*

In conclusion, I may remind the reader, that but for

* Raffles's Hist. of Java, vol. i. p. 25.—Ed. Phil. Journ. vol. iii. p. 389.

the accidental presence of Sir Stamford Raffles, then governor of Java, we should scarcely have heard in Europe of this tremendous catastrophe. He required all the residents in the various districts under his authority to send in a statement of the circumstances which occurred within their own knowledge; but, valuable as were their communications, they are often calculated to excite rather than to satisfy the curiosity of the geologist. They mention, that similar effects, though in a less degree, had, about seven years before, accompanied an eruption of Carang Assam, a volcano in the island of Bali, west of Sumatra; but no particulars of that great catastrophe are recorded.*

Caraccas, 1812.—On the 26th of March, 1812, several violent shocks of an earthquake were felt in Caraccas. The surface undulated like a boiling liquid, and terrific sounds were heard underground. The whole city with its splendid churches was in an instant a heap of ruins, under which 10,000 of the inhabitants were buried. On the 5th of April, enormous rocks were detached from the mountains. It was believed that the mountain Silla lost from 300 to 360 feet of its height by subsidence; but this was an opinion not founded on any measurement. On the 27th of April, a volcano in St. Vincent's threw out ashes; and on the 30th, lava flowed from its crater into the sea, while its explosions were heard at a distance equal to that between Vesuvius and Switzerland, the sound being transmitted, as Humboldt supposes, through the ground. During the earthquake which destroyed Caraccas, an immense quantity of water was thrown out at Valecillo, near Valencia, as also at Porto Cabello,

* Life and Services of Sir Stamford Raffles, p. 241. London, 1830.

through openings in the earth ; and in the Lake Maracaybo the water sank. Humboldt observed that the Cordilleras, composed of gneiss and mica slate, and the country immediately at their foot, were more violently shaken than the plains.*

South Carolina, 1811.—New Madrid. — Previous to the destruction of La Guayra and Caraccas, in 1812, South Carolina was convulsed by earthquakes ; and the shocks continued till those cities were destroyed. The valley also of the Mississippi, from the village of New Madrid to the mouth of the Ohio in one direction, and to the St. Francis in another, was convulsed to such a degree as to create lakes and islands. Flint, the geographer, who visited the country seven years after the event, informs us, that a tract of many miles in extent, near the Little Prairie, became covered with water three or four feet deep ; and when the water disappeared, a stratum of sand was left in its place. Large lakes of twenty miles in extent were formed in the course of an hour, and others were drained. The grave-yard at New Madrid was precipitated into the bed of the Mississippi ; and it is stated that the ground whereon the town is built, and the river bank for fifteen miles above, sank eight feet below their former level.† The neighbouring forest presented for some years afterwards “ a singular scene of confusion ; the trees standing inclined in every direction, and many having their trunks and branches broken.” ‡

The inhabitants relate that the earth rose in great undulations ; and when these reached a certain fearful

* Humboldt's Pers. Nar. vol. iv. p. 12. ; and Ed. Phil. Journ. vol. i. p. 272., 1819.

† Cramer's Navigator, p. 243. Pittsburgh, 1821.

‡ Long's Exped. to the Rocky Mountains, vol. iii. p. 184.

height, the soil burst, and vast volumes of water, sand, and pit-coal were discharged as high as the tops of the trees. Flint saw hundreds of these deep chasms remaining in an alluvial soil, seven years after. The people in the country, although inexperienced in such convulsions, had remarked that the chasms in the earth were in a direction from S.W. to N.E.; and they accordingly felled the tallest trees; and laying them at right angles to the chasms, stationed themselves upon them. By this invention, when chasms opened more than once under these trees, several persons were prevented from being swallowed up.* At one period during this earthquake, the ground not far below New Madrid swelled up so as to arrest the Mississippi in its course, and to cause a temporary reflux of its waves. The motion of some of the shocks was horizontal, and of others perpendicular; and the vertical movement is said to have been much less desolating than the horizontal. If this be often the case, those shocks which injure cities least may produce the greatest alteration of level.

Aleutian Islands, 1806.—In the year 1806, a new island, in the form of a peak, with some low conical hills upon it, rose from the sea among the Aleutian Islands, east of Kamtschatka. According to Langsdorf †, it was four geographical miles in circumference; and Von Buch infers, from its magnitude, and from its not having again subsided below the level of the sea, that it did not consist merely of ejected matter, but of a solid rock of trachyte upheaved.‡ Another extraordinary eruption happened in the spring of the year

* Silliman's Journ., Jan. 1829.

† Bemerkungen auf einer Reise um die Welt. bd. ii. s. 209.

‡ Neue Allgem. Geogr. Ephemer. bd. iii. s. 348.

1814, in the sea near Unalaschka, in the same archipelago. A new isle was then produced of considerable size, and with a peak three thousand feet high, which remained standing for a year afterwards, though with somewhat diminished height.

Although it is not improbable that earthquakes accompanying these tremendous eruptions may have heaved up part of the bed of the sea, yet the circumstance of the islands not having disappeared like Sabrina (see p. 226.) may have arisen from the emission of lava. If Jorullo, for example, in 1759, had risen from a shallow sea to the height of 1600 feet, instead of attaining that elevation above the Mexican plateau, the massive current of basaltic lava which poured out from its crater would have enabled it to withstand, for a long period, the action of a turbulent sea.

Reflections on the earthquakes of the nineteenth century. — We are now about to pass on to the events of the eighteenth century ; but, before we leave the consideration of those already enumerated, let us pause for a moment, and reflect how many remarkable facts of geological interest are afforded by the earthquakes above described, though they constitute but a small part of the convulsions even of the last forty years. New rocks have risen from the waters ; new hot springs have burst out, and the temperature of another has been raised ; the coast of Chili has been thrice permanently elevated ; a considerable tract in the delta of the Indus has sunk down, and some of its shallow channels have become navigable ; an adjoining part of the same district, upwards of fifty miles in length and sixteen in breadth, has been raised about ten feet above its former level ; the town of Tomboro has been submerged, and twelve

thousand of the inhabitants of Sumbawa have been destroyed. Yet, with a knowledge of these terrific catastrophes, witnessed during so brief a period by the present generation, will the geologist declare with perfect composure that the earth has at length settled into a state of repose? Will he continue to assert that the changes of relative level of land and sea, so common in former ages of the world, have now ceased? If, in the face of so many striking facts, he persists in maintaining this favourite dogma, it is in vain to hope that, by accumulating the proofs of similar convulsions during a series of antecedent ages, we shall shake his tenacity of purpose : —

Si fractus illabatur orbis
Impavidum ferient ruinæ.

EARTHQUAKES OF THE EIGHTEENTH CENTURY.

Quito, 1797. — On the morning of February 4th, 1797, the volcano of Tunguragua in Quito, and the surrounding district, for forty leagues from south to north, and twenty leagues from west to east, experienced an undulating movement, which lasted four minutes. The same shock was felt over a tract of 170 leagues from south to north, from Piura to Popayan; and 140 from west to east, from the sea to the river Napo. In the smaller district first mentioned, where the movement was more intense, every town was levelled to the ground; and Riobamba, Quero, and other places, were buried under masses detached from the mountains. At the foot of Tunguragua the earth was rent open in several places; and streams of water and fetid mud, called “moya,” poured out, overflowing and wasting every thing. In

valleys one thousand feet broad, the water of these floods reached to the height of six hundred feet: and the mud deposit barred up the course of the river, so as to form lakes, which in some places continued for more than eighty days. Flames and suffocating vapours escaped from the lake Quilotoa, and killed all the cattle on its shores. The shocks continued all February and March; and on the fifth of April they recurred with almost as much violence as at first. We are told that the form of the surface in the district most shaken was entirely altered, but no exact measurements are given whereby we may estimate the degree of elevation or subsidence.* Indeed it would be difficult, except in the immediate neighbourhood of the sea, to obtain any certain standard of comparison, if the levels were really as much altered as the narrations imply.

Cumana, 1797.—In the same year, on the 14th of December, the small Antilles experienced subterranean movements, and four-fifths of the town of Cumana was shaken down by a vertical shock. The form of the shoal of Mornerouge, at the mouth of the river Bourdones, was changed by an upheaving of the ground.†

Quebec, 1791.—We learn from Captain Bayfield's memoirs, that earthquakes are very frequent on the shore of the estuary of the St. Lawrence, of force sufficient at times to split walls and throw down chimneys. Such were the effects experienced in December, 1791, in St. Paul's Bay, about fifty miles N E. from Quebec; and the inhabitants say, that about every

* Cavanilles, *Journ. de Phys.* tome xlix. p. 220. Gilbert's *Annalen*, bd. vi. p. 67. Humboldt's *Voy.* p. 317.

† Humboldt's *Voy.*, *Relat. Hist.*, part i. p. 309.

twenty-five years a violent earthquake returns, which lasts forty days. In the History of Canada, it is stated, that, in 1663, a tremendous convulsion lasted six months, extending from Quebec to Tadeausac,—a distance of about 130 miles. The ice on the river was broken up, and many landslips caused.*

Caraccas, 1790. — In the Caraccas, near where the Caura joins the Orinoco, between the towns San Pedro de Alcantara and San Francisco de Aripao, an earthquake, on St. Matthew's day, 1790, caused a sinking in of the granitic soil, and left a lake eight hundred yards in diameter, and from eighty to one hundred in depth. It was a portion of the forest of Aripao which subsided, and the trees remained green for several months under water.†

Sicily, 1790. — On the 18th of March in the same year, at S. Maria di Niscemi, some miles from Terra-nuova, near the south coast of Sicily, the ground gradually sank down for a circumference of three Italian miles, during seven shocks; and, in one place, to the depth of thirty feet. It continued to subside to the end of the month. Several fissures sent forth sulphur, petroleum, steam, and hot water; and a stream of mud, which flowed for two hours, and covered a space sixty feet long, and thirty broad. This happened far from both the ancient and modern volcanic district, in a group of strata consisting chiefly of blue clay.‡

Java, 1786. — About the year 1786, an earthquake was felt at intervals, for the period of four months, in the neighbourhood of Batur, in Java, and an eruption followed. Various rents were formed, which emitted

* Macgregor's Travels in America.

† Humboldt's Voy., Relat. Hist., part ii. p. 632.

‡ Ferrara, Camp. fl., p. 51.

a sulphureous vapour; separate tracts sunk away, and were swallowed by the earth. Into one of these the rivulet Dotog entered, and afterwards continued to follow a subterraneous course. The village of Jam-pang was buried in the ground, with thirty-eight of its inhabitants, who had not time to escape. We are indebted to Dr. Horsfield for having verified the above-mentioned facts.*

Japan Isles, 1783.—In the province of Sinano, in the isle of Nifon, the volcanic mountain of Asamayama, situated north-east of the town of Komoro, was in violent eruption August 1. 1783. The waters of several rivers are said to have boiled, and one of the largest of them, Yone-garva, deluged the country. The eruption was preceded by a frightful earthquake; gulphs are said to have opened every where, and many towns to have been swallowed up, while others were subsequently buried by lava.†

* Batav. Trans. vol. viii. p. 141.

† Humboldt, *Fragmens Asiatiques, &c.* tom. i. p. 229.

CHAPTER XVI.

EARTHQUAKE IN CALABRIA, 1783.

Earthquake in Calabria, February 5. 1783 — Shocks continued to the end of the year 1786 — Authorities — Area convulsed — Geological structure of the district — Difficulty of ascertaining changes of level — Subsidence of the quay at Messina — Shift or fault in the Round Tower of Terranova — Movement in the stones of two obelisks — Opening and closing of fissures — Large edifices engulfed — Dimensions of new caverns and fissures — Gradual closing in of rents — Bounding of detached masses into the air — Landslips — Buildings transported entire to great distances — New lakes — Currents of mud — Funnel-shaped hollows in alluvial plains — Fall of cliffs, and shore near Scilla inundated — State of Stromboli and Etna during the shocks — How earthquakes contribute to the formation of valleys — Concluding remarks.

Calabria, 1783. — Of the numerous earthquakes which have occurred in different parts of the globe, during the last hundred years, that of Calabria, in 1783, is almost the only one of which the geologist can be said to have such a circumstantial account as to enable him fully to appreciate the changes which this cause is capable of producing in the lapse of ages. The shocks began in February, 1783, and lasted for nearly four years, to the end of 1786. Neither in duration, nor in violence, nor in the extent of territory moved, was this convulsion remarkable, when contrasted with many experienced in other countries,

both during the last and present century; nor were the alterations which it occasioned in the relative level of hill and valley, land and sea, so great as those effected by some subterranean movements in South America, in later times. The importance of the earthquake in question arises from the circumstance, that Calabria is the only spot hitherto visited, both during and after the convulsions, by men possessing sufficient leisure, zeal, and scientific information, to enable them to collect and describe with accuracy the physical facts which throw light on geological questions.

Fig. 54.



Authorities.—Among the numerous authorities, Vienzio, physician to the King of Naples, transmitted to the court a regular statement of his observations during the continuance of the shocks; and his narrative is drawn up with care and clearness.* Francesco Antonio Grimaldi, then secretary of war, visited the different provinces at the king's command, and published a most detailed description of the permanent changes in the surface.† He measured the length, breadth, and depth of the different fissures and gulps which opened, and ascertained their number in many provinces. His comments, moreover, on the reports of the inhabitants, and his explanations of their relations, are judicious and instructive. Pignataro, a physician residing at Monteleone, a town placed in the very centre of the convulsions, kept a register of the shocks, distinguishing them into four classes, according to their degree of violence. From his work, it appears that, in the year 1783, the number was 949, of which 501 were shocks of the first degree of force; and in the following year there were 151, of which 98 were of the first magnitude.

Count Ippolito, also, and many others, wrote descriptions of the earthquake; and the Royal Academy of Naples, not satisfied with these and other observations, sent a deputation from their own body into Calabria, before the shocks had ceased, who were accompanied by artists instructed to illustrate by drawings the physical changes of the district, and the state of ruined towns and edifices. Unfortunately these artists were not very successful in their repre-

* *Istoria de' Tremuoti della Calabria del 1783.*

† *Descriz. de' Tremuoti Accad. nelle Calabria nel 1783.*
Napoli, 1784.

sentations of the condition of the country, particularly when they attempted to express, on a large scale, the extraordinary revolutions which many of the great and minor river-courses underwent. But many of the plates published by the Academy are valuable; and as they are little known, I shall frequently avail myself of them to illustrate the facts about to be described.*

In addition to these Neapolitan sources of information, our countryman, Sir William Hamilton, surveyed the district, not without some personal risk, before the shocks had ceased; and his sketch, published in the Philosophical Transactions, supplies many facts that would otherwise have been lost. He has explained, in a rational manner, many events which, as related in the language of some eyewitnesses, appeared marvellous and incredible. Dolomieu also examined Calabria during the catastrophe, and wrote an account of the earthquake, correcting a mistake into which Hamilton had fallen, who supposed that a part of the tract shaken had consisted of volcanic tuff. It is, indeed, a circumstance which enhances the geological interest of the commotions which so often modify the surface of Calabria, that they are confined to a country where there are neither ancient nor modern rocks of volcanic or trappean origin; so that at some future time, when the era of disturbance shall have passed by, the cause of former revolutions will be as latent as in parts of Great Britain now occupied exclusively by ancient marine formations.

Extent of the area convulsed. — The convulsion of the earth, sea, and air extended over the whole of

* Istoria de' Fenomeni del Tremoto, &c. nell' An. 1783, posta in luce dalla Real. Accad., &c. di Nap. Napoli, 1783. fol.

Calabria Ultra, the south-east part of Calabria Citra, and across the sea to Messina and its environs; a district lying between the 38th and 39th degrees of latitude. The concussion was perceptible over a great part of Sicily, and as far north as Naples; but the surface over which the shocks acted so forcibly as to excite intense alarm did not generally exceed five hundred square miles in area. The soil of that part of Calabria is composed chiefly, like the southern part of Sicily, of calcareo-argillaceous strata of great thickness, containing marine shells. This clay is sometimes associated with beds of sand and limestone. For the most part these formations resemble in appearance and consistency the Subapennine marls, with their accompanying sands and sandstones; and the whole group bears considerable resemblance, in the yielding nature of its materials, to most of our tertiary deposits in France and England. Chronologically considered, however, the Calabrian formations are comparatively of very modern date, and abound in fossil shells referrible to species now living in the Mediterranean.

We learn from Vivenzio that, on the 20th and 26th of March, 1783, earthquakes occurred in the islands of Zante, Cephalonia, and St. Maura; and in the last-mentioned island several public edifices and private houses were overthrown, and many people destroyed. It has been already shown that the Ionian Islands fall within the line of the same great volcanic region as Calabria; so that both earthquakes were probably derived from a common source, and it is not improbable that the bed of the whole intermediate sea was convulsed.

If the city of Oppido, in Calabria Ultra, be taken as a centre, and round that centre a circle be described, with a radius of twenty-two miles, this space will com-

prehend the surface of the country which suffered the greatest alteration, and where all the towns and villages were destroyed. The first shock, of February 5th, 1783, threw down, in two minutes, the greater part of the houses in all the cities, towns, and villages, from the western flanks of the Apennines in Calabria Ultra to Messina in Sicily, and convulsed the whole surface of the country. Another occurred on the 28th of March, with almost equal violence. The granitic chain which passes through Calabria from north to south, and attains the height of many thousand feet, was shaken but slightly by the first shock, but more rudely by some which followed.

Some writers have asserted that the wave-like movements which were propagated through the recent strata, from west to east, became very violent when they reached the point of junction with the granite, as if a reaction was produced where the undulatory movement of the soft strata was suddenly arrested by the more solid rocks. But the statement of Dolomieu on this subject is most interesting, and, perhaps, in a geological point of view, the most important of all the observations which are recorded.*

The Apennines, he says, which consist in great part of hard and solid granite, with some micaceous and argillaceous schists, form bare mountains with steep sides, and exhibit marks of great degradation. At their base newer strata are seen of sand and clay, mingled with shells; a marine deposit containing such ingredients as would result from the decomposition of granite. The surface of this newer (*tertiary*) formation constitutes what is called the plain of Calabria — a platform

* Dissertation on the Calabrian Earthquake, &c., translated in Pinkerton's Voyages and Travels, vol. v.

which is flat and level, except where intersected by narrow valleys or ravines, which rivers and torrents have excavated sometimes to the depth of six hundred feet. The sides of these ravines are almost perpendicular; for the superior stratum, being bound together by the roots of trees, prevents the formation of a sloping bank. The usual effect of the earthquake, he continues, was to disconnect all those masses which either had not sufficient bases for their bulk, or which were supported only by lateral adherence. Hence it follows that throughout almost the whole length of the chain the soil which adhered to the granite at the base of the mountains Caulone, Esope, Sagra, and Aspramonte, slid over the solid and steeply inclined nucleus, and descended somewhat lower, leaving almost uninterruptedly from St. George to beyond St. Christina, a distance of from nine to ten miles, a chasm between the solid granitic nucleus and the sandy soil. Many lands slipping thus were carried to a considerable distance from their former position, so as entirely to cover others; and disputes arose as to whom the property which had thus shifted its place should belong.

From this account of Dolomieu we might anticipate, as the result of a continuance of such earthquakes, first, a longitudinal valley following the line of junction of the older and newer rocks; secondly, greater disturbance in the newer strata near the point of contact than at a greater distance from the mountains; phenomena very common in other parts of Italy at the junction of the Apennine and Subapennine formations.

The surface of the country often heaved like the billows of a swelling sea, which produced a swimming in the head, like sea-sickness. It is particularly stated,

in almost all the accounts, that just before each shock the clouds appeared motionless ; and, although no explanation is offered of this phenomenon, it is obviously the same as that observed in a ship at sea when it pitches violently. The clouds seem arrested in their career as often as the vessel rises in a direction contrary to their course ; so that the Calabrians must have experienced precisely the same motion on the land.

Trees, supported by their trunks, sometimes bent during the shocks to the earth, and touched it with their tops. This is mentioned as a well-known fact by Dolomieu ; and he assures us that he was always on his guard against the spirit of exaggeration in which the vulgar are ever ready to indulge when relating these wonderful occurrences.

It is impossible to suppose that these waves, which are described in Italy and other regions of earthquakes as passing along the solid surface of the earth in a given direction like a billow on the sea, have any strict analogy with the undulations of a fluid. They are doubtless the effects of vibrations, radiating from some deep-seated point, each of which on reaching the surface lifts up the ground, and then allows it again to subside. As the distance between the source of the subterranean movement and the surface must vary according to the outline of the country, so the vibratory jar will reach different points in succession.

I shall now consider, in the first place, that class of physical changes produced by the earthquake which are connected with alterations in the relative level of the different parts of the land ; and afterwards describe those which are more immediately connected with the derangement of the regular drainage of the

country, and where the force of running water co-operated with that of the earthquake.

Difficulty of ascertaining changes of level.—In regard to alterations of relative level, none of the accounts establish that they were on a considerable scale; but it must always be remembered that, in proportion to the area moved is the difficulty of proving that the general level has undergone any change, unless the sea-coast happens to have participated in the principal movement. Even then it is often impossible to determine whether an elevation or depression even of several feet has occurred, because there is nothing to attract notice in a band of shingle and sand of unequal breadth above the level of the sea running parallel to a coast; such bands generally marking the point reached by the waves during spring tides, or the most violent tempests. The scientific investigator has not sufficient topographical knowledge to discover whether the extent of beach has diminished or increased; and he who has the necessary local information scarcely ever feels any interest in ascertaining the amount of the rise or fall of the ground. Add to this the great difficulty of making correct observations, in consequence of the enormous waves which roll in upon a coast during an earthquake, and efface every landmark near the shore.

Subsidence of the quay at Messina.—It is evidently in seaports alone that we can look for very accurate indications of slight changes of level; and when we find them, we may presume that they would not be rare at other points, if equal facilities of comparing relative altitudes were afforded. Grimaldi states (and his account is confirmed by Hamilton and others), that at Messina, in Sicily, the shore was rent; and the soil

along the port, which before the shock was perfectly level, was found afterwards to be inclined towards the sea,—the sea itself near the “Banchina” becoming deeper, and its bottom in several places disordered. The quay also sunk down about fourteen inches below the level of the sea, and the houses in its vicinity were much fissured. (*Phil. Trans.* 1783.)

Among various proofs of partial elevation and depression in the interior, the Academicians mention, in their Survey, that the ground was sometimes on the same level on both sides of new ravines and fissures, but sometimes there had been a considerable shifting, either by the upheaving of one side, or the subsidence of the other. Thus, on the sides of long rents in the territory of Soriano, the stratified masses had altered their relative position to the extent of from eight to fourteen palms (six to ten and a half feet).

Polistena. — Similar shifts in the strata are alluded to in the territory of Polistena, where there appeared

Fig. 55.



Deep fissure, near Polistena, caused by the earthquake of 1783.

innumerable fissures in the earth. One of these was of great length and depth; and in parts the level of the corresponding sides was greatly changed. (See Fig. 55.)

Terranuova. — In the town of Terranuova some houses were seen uplifted above the common level, and others adjoining sunk down into the earth. In several streets the soil appeared thrust up, and abutted against the walls of houses : a large circular tower of solid masonry, part of which had withstood the general destruction, was divided by a vertical rent, and one side was upraised, and the foundations heaved out of the ground. It was compared by the Academicians to a great tooth half extracted from the alveolus, with the upper part of the fangs exposed. (See Fig. 56.)

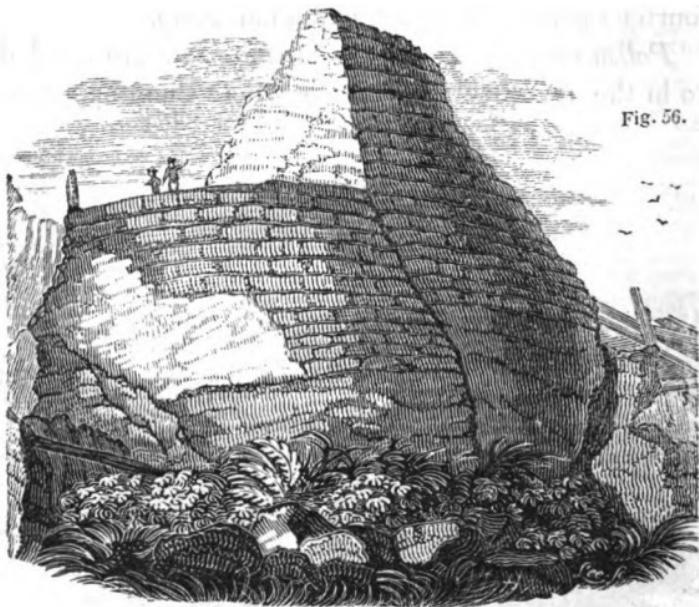


Fig. 56.

Shift or "fault" in the round tower of Terranuova in Calabria, occasioned by the earthquake of 1783.

Along the line of this shift, or “fault,” as it would be termed technically by miners, the walls were found to adhere firmly to each other, and to fit so well, that the only signs of their having been disunited was the want of correspondence in the courses of stone on either side of the rent.

Dolomieu saw a stone well in the convent of the Augustins at Terranuova, which had the appearance of having been driven out of the earth. It resembled a small tower eight or nine feet in height, and a little inclined. This effect, he says, was produced by the consolidation and consequent sinking of the sandy soil in which the well was dug.

In some walls which had been thrown down, or violently shaken, in Monteleone, the separate stones were parted from the mortar, so as to leave an exact mould where they had rested; whereas in other cases the mortar was ground to dust between the stones.

It appears that the wave-like motions, and those which are called vorticose or whirling in a vortex, often produced effects of the most capricious kind. Thus, in some streets of Monteleone, every house was thrown down but one; in others, all but two; and the buildings which were spared were often scarcely in the least degree injured.

In many cities of Calabria, all the most solid buildings were thrown down, while those which were slightly built escaped; but at Rosarno, as also at Messina in Sicily, it was precisely the reverse, the massive edifices being the only ones that stood. Two obelisks (Fig. 57.) placed at the extremities of a magnificent façade in the convent of S. Bruno, in a small town called Stefano del Bosco, were observed to have undergone a movement of a singular kind. The shock

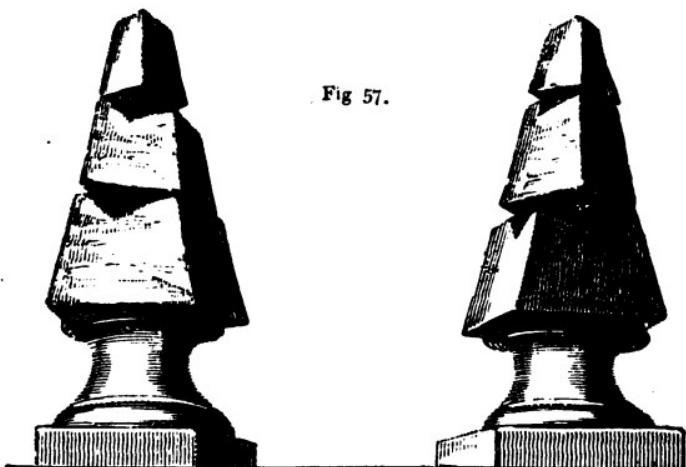


Fig 57.

Shift in the stones of two obelisks in the Convent of S. Bruno.

which agitated the building is described as having been horizontal and vorticoso. The pedestal of each obelisk remained in its original place ; but the separate stones above were turned partially round, and removed sometimes nine inches from their position without falling. It has been suggested, however, that this kind of displacement may be due to a vibratory rather than a whirling motion.*

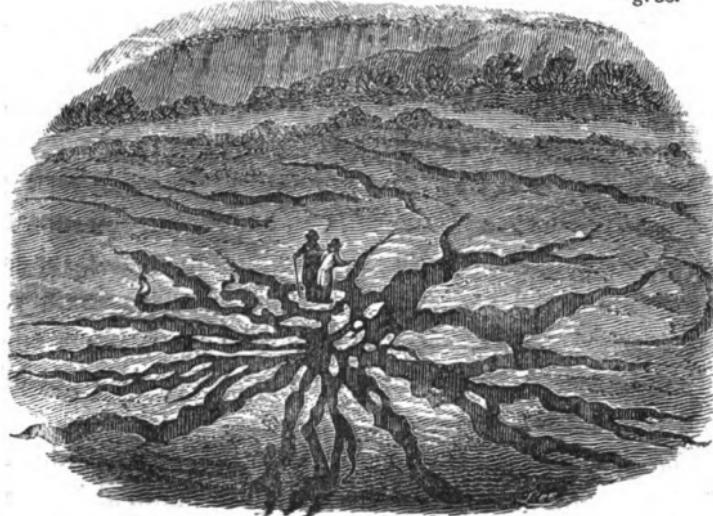
Fissures.—It appears evident that a great part of the rending and fissuring of the ground was the effect of a violent motion from below upwards ; and in a multitude of cases where the rents and chasms opened and closed alternately, we must suppose that the earth was by turns heaved up, and then let fall again. We may conceive the same effect to be produced on a small scale, if, by some mechanical force, a pavement composed of large flags of stone should be raised up, and then allowed to fall suddenly, so as to resume its

* Darwin's Journal, p. 376.

original position. If any small pebbles happened to be lying on the line of contact of two flags, they would fall into the opening when the pavement rose, and be swallowed up, so that no trace of them would appear after the subsidence of the stones. In the same manner, when the earth was upheaved, large houses, trees, cattle, and men were engulfed in an instant in chasms and fissures; and when the ground sank down again, the earth closed upon them, so that no vestige of them was discoverable on the surface. In many instances, individuals were swallowed up by one shock, and then thrown out again alive, together with large jets of water, by the shock which immediately succeeded.

At Jerocarne, a country which, according to the Academicians, was *lacerated* in a most extraordinary manner, the fissures ran in every direction "like cracks on a broken pane of glass" (see Fig. 58.); and,

Fig. 58.



Fissures near Jerocarne, in Calabria, caused by the earthquake of 1783.
as a great portion of them remained open after the shocks, it is very possible that this country was perma-

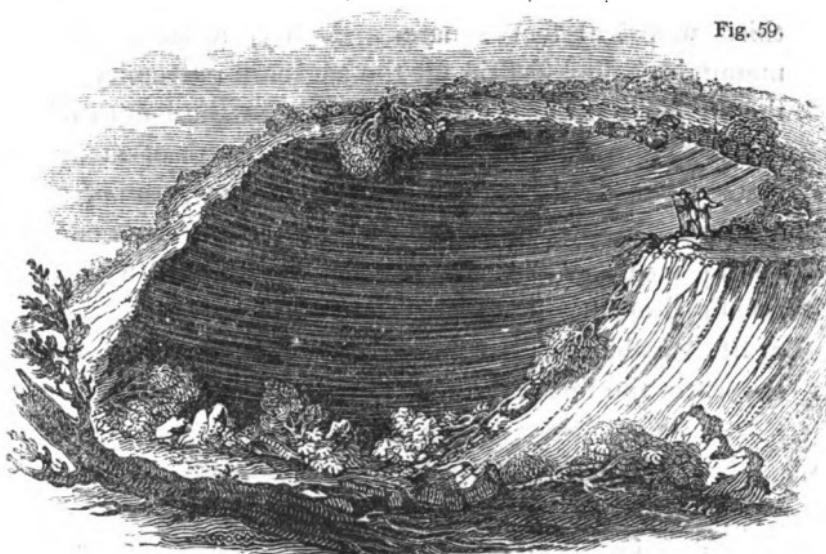
nently upraised. It was usual, as we learn from Dolomieu, for the chasms and fissures throughout Calabria to run parallel to the course of some pre-existing gorges in their neighbourhood.

Houses engulfed. — In the vicinity of Oppido, the central point from which the earthquake diffused its violent movements, many houses were swallowed up by the yawning earth, which closed immediately over them. In the adjacent district, also, of Cannamaria four farm-houses, several oil-stores, and some spacious dwelling-houses were so completely engulfed in one chasm, that not a vestige of them was afterwards discernible. The same phenomenon occurred at Terranova, S. Christina, and Sinopoli. The Academicians state particularly, that when deep abysses had opened in the argillaceous strata of Terranova, and houses had sunk into them, the sides of the chasms closed with such violence, that, on excavating afterwards to recover articles of value, the workmen found the contents and detached parts of the buildings jammed together so as to become one compact mass. It is unnecessary to accumulate examples of similar occurrences; but so many are well authenticated during this earthquake in Calabria, that we may, without hesitation, yield assent to the accounts of catastrophes of the same kind repeated again and again in history, where whole towns are declared to have been engulfed, and nothing but a pool of water or tract of sand left in their place.

Chasm formed near Oppido. — On the sloping side of a hill near Oppido a great chasm opened; and, although a large quantity of soil was precipitated into the abyss, together with a considerable number of olive-trees and part of a vineyard, a great gulph remained after the

shock, in the form of an amphitheatre, 500 feet long and 200 feet deep. (See Fig. 59.)

Fig. 59.



Chasm formed by the earthquake of 1783 near Oppido, in Calabria.

Dimensions of new fissures and chasms. — According to Grimaldi, many fissures and chasms, formed by the first shock of February 5th, were greatly widened, lengthened, and deepened by the violent convulsions of March 28th. In the territory of San Fili this observer found a new ravine, half a mile in length, two feet and a half broad, and twenty-five feet deep; and another of similar dimensions in the territory of Rosarno. A ravine *nearly a mile long*, 105 feet broad, and thirty feet deep, opened in the district of Plaisano, where, also, two gulphs were caused — one in a place called Cerzulle, three quarters of a mile long, 150 feet broad, and above *one hundred feet deep*; and another at La Fortuna, nearly a quarter of a mile long, above thirty feet in breadth, and no less than 225 feet deep.

In the district of Fosolano three gulphs opened;

one of these measured 300 feet square, and above thirty feet deep; another was nearly half a mile long, fifteen feet broad, and above thirty feet deep; the third was 750 feet square. Lastly, a calcareous mountain, called Zefirio, at the southern extremity of the Italian peninsula, was cleft in two for the length of nearly half a mile, and an irregular breadth of many feet. Some of these chasms were in the form of a crescent. The annexed cut (Fig. 60.) represents one by no means remarkable for its dimensions, which remained open by the side of a small pass over the hill of St. Angelo, near Soriano. The small river Mesima is seen in the foreground.



Fig. 60.

Chasm in the hill of St. Angelo, near Soriano, in Calabria, caused by the earthquake of 1783.

Formation of new lakes. — In the vicinity of Seminara, a lake was suddenly formed by the opening of a great chasm, from the bottom of which water issued. This lake was called Lago del Tolfilo. It extended 1785 feet in length, by 937 in breadth, and 52 in

depth. The inhabitants, dreading the miasma of this stagnant pool, endeavoured, at great cost, to drain it by canals, but without success, as it was fed by springs issuing from the bottom of the deep chasm. A small circular subsidence occurred not far from Polistena, of which a representation is given below.



Fig. 61.

Circular pond near Polistena, in Calabria, caused by the earthquake in 1783.

Gradual closing in of fissures. — Sir W. Hamilton was shown several deep fissures in the vicinity of Mileto, which, although not one of them was above a foot in breadth, had opened so wide during the earthquake as to swallow up an ox and nearly one hundred goats. The Academicians also found, on their return through districts which they had passed at the commencement of their tour, that many rents had, in that short interval, gradually closed in, so that their width had diminished several feet, and the opposite walls had sometimes nearly met. It is natural that this should happen in argillaceous strata, while, in more solid rocks, we may expect that fissures will remain open

for ages. Should this be ascertained to be a general fact in countries convulsed by earthquakes, it may afford a satisfactory explanation of a common phenomenon in mineral veins. Such veins often retain their full size so long as the rocks consist of limestone, granite, or other indurated materials ; but they contract their dimensions, become mere threads, or are even entirely cut off, where masses of an argillaceous nature are interposed. If we suppose the filling up of fissures with metallic and other ingredients to be a process requiring ages for its completion, it is obvious that the opposite walls of rents, where strata consist of yielding materials, must collapse or approach very near to each other before sufficient time is allowed for the accretion of a large quantity of vein-stone.

Thermal waters augmented. — It is stated by Grimaldi, that the thermal waters of St. Eufemia, in Terra di Amato, which first burst out during the earthquake of 1638, acquired, in February, 1783, an augmentation both in quantity and degree of heat. This fact appears to indicate a connection between the heat of the interior and the fissures caused by the Calabrian earthquakes, notwithstanding the absence of volcanic rocks, either ancient or modern, in that district.

Bounding of detached masses into the air. — The violence of the movement of the ground upwards was singularly illustrated by what the Academicians call the "sbalzo," or bounding into the air, to the height of several yards, of masses slightly adhering to the surface. In some towns, a great part of the pavement stones were thrown up, and found lying with their lower sides uppermost. In these cases, we must suppose that they were propelled upwards by the

momentum which they had acquired; and that the adhesion of one end of the mass being greater than that of the other, a rotatory motion had been communicated to them. When the stone was projected to a sufficient height to perform somewhat more than a quarter of a revolution in the air, it pitched down on its edge, and fell with its lower side uppermost.

Effects of earthquakes on the excavation of valleys.—The next class of effects to be considered, are those more immediately connected with the formation of valleys, in which the action of water was often combined with that of the earthquake. The country agitated was composed, as before stated, chiefly of argillaceous strata, intersected by deep narrow valleys, sometimes from 500 to 600 feet deep. As the boundary cliffs were in great part vertical, it will readily be conceived that, amidst the various movements of the earth, the precipices overhanging rivers, being without support on one side, were often thrown down. We find, indeed, that inundations produced by obstructions in river-courses are among the most disastrous consequences of great earthquakes in all parts of the world for the alluvial plains in the bottoms of valleys are usually the most fertile and well-peopled parts of the whole country; and whether the site of a town is above or below a temporary barrier in the channel of a river, it is exposed to injury by the waters either of a lake or flood.

Landslips.—From each side of the deep valley or ravine of Terranuova, enormous masses of the adjoining flat country were detached, and cast down into the course of the river, so as to give rise to great lakes. Oaks, olive-trees, vineyards, and corn, were often seen growing at the bottom of the ravine, as little injured

as their former companions, which still continued to flourish in the plain above, at least 500 feet higher, and at the distance of about three quarters of a mile. In one part of this ravine was an enormous mass, 200 feet high, and about 400 feet at its base, which had been detached by some former earthquake. It is well attested, that this mass travelled down the ravine nearly four miles, having been put in motion by the earthquake of the 5th of February. Hamilton, after examining the spot, declared that this phenomenon might be accounted for by the declivity of the valley, the great abundance of rain which fell, and the great weight of the alluvial matter which pressed behind it. Dolomieu also alludes to the fresh impulse derived from other masses falling, and pressing upon the rear of those first set in motion.

The first account sent to Naples of the two great slides or landslips above alluded to, which caused a great lake near Terranova, was couched in these words:—"Two mountains on the opposite sides of a valley walked from their original position until they met in the middle of the plain, and there joining together, they intercepted the course of a river," &c. The expressions here used resemble singularly those applied to phenomena, probably very analogous, which are said to have occurred at Fez, during the great Lisbon earthquake, as also in Jamaica and Java at other periods.

Not far from Soriano, which was levelled to the ground by the great shock of February, a small valley, containing a beautiful olive-grove, called Fra Ramondo, underwent a most extraordinary revolution. Innumerable fissures first traversed the river-plain in all directions, and absorbed the water until the argilla-

aceous substratum became soaked, so that a great part of it was reduced to a state of fluid paste. Strange alterations in the outline of the ground were the consequence, as the soil to a great depth was easily moulded into any form. In addition to this change, the ruins of the neighbouring hills were precipitated into the hollow; and while many olives were uprooted, others remained growing on the fallen masses, and inclined at various angles (see Fig. 62). The small river Caridi was entirely concealed for many days; and when at length it reappeared, it had shaped for itself an entirely new channel.

Fig. 62.

*Changes of the surface at Fra Ramondo, near Soriano, in Calabria.*

1, Portion of a hill covered with olives thrown down.

2, New bed of the river Caridi.

3, Town of Soriano.

Buildings transported entire to great distances.— Near Seminara, an extensive olive-ground and orchard were hurled to a distance of two hundred feet, into a

valley sixty feet in depth. At the same time a deep chasm was riven in another part of the high platform from which the orchard had been detached, and the river immediately entered the fissure, leaving its former bed completely dry. A small inhabited house, standing on the mass of earth carried down into the valley, went along with it entire, and without injury to the inhabitants. The olive-trees, also, continued to grow on the land which had slid into the valley, and bore the same year an abundant crop of fruit.

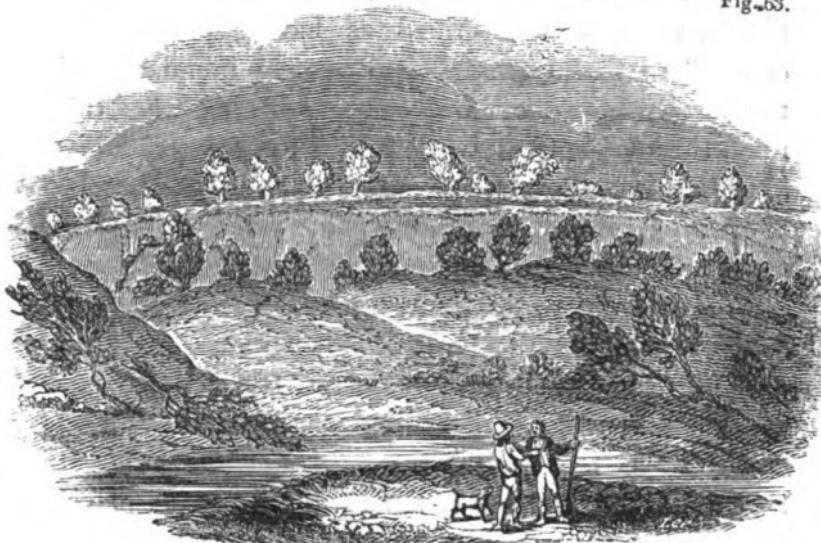
Two tracts of land on which a great part of the town of Polistena stood, consisting of some hundreds of houses, were detached into a contiguous ravine, and nearly across it, about half a mile from their original site; and what is most extraordinary, several of the inhabitants were dug out from the ruins alive and unhurt.

Two tenements, near Mileto, called the Macini and Vaticano, occupying an extent of ground about a mile long, and half a mile broad, were carried for a mile down a valley. A thatched cottage, together with large olive and mulberry trees, most of which remained erect, were carried uninjured to this extraordinary distance. According to Hamilton, the surface removed had been long undermined by rivulets, which were afterwards in full view on the bare spot deserted by the tenements. The earthquake seems to have opened a passage in the adjoining argillaceous hills, which admitted water charged with loose soil into the subterranean channels of the rivulets immediately under the tenements, so that the foundations of the ground set in motion by the earthquake were loosened. Another example of subsidence, where the edifices were not destroyed, is mentioned by Grimaldi, as having taken place in the city of Catanzaro, the capital of the pro-

vince of that name. The houses in the quarter called San Giuseppe subsided with the ground to various depths from two to four feet, but the buildings remained uninjured.

It would be tedious, and our space would not permit us, to follow the different authors through their local details of landslips produced in minor valleys; but they are highly interesting, as showing to how great an extent the power of rivers to widen valleys, and to carry away large portions of soil towards the sea, is increased where earthquakes are of periodical occurrence. Among other territories, that of Cinquefrondi

Fig. 63.



Landslips near Cinquefrondi, caused by the earthquake of 1783.

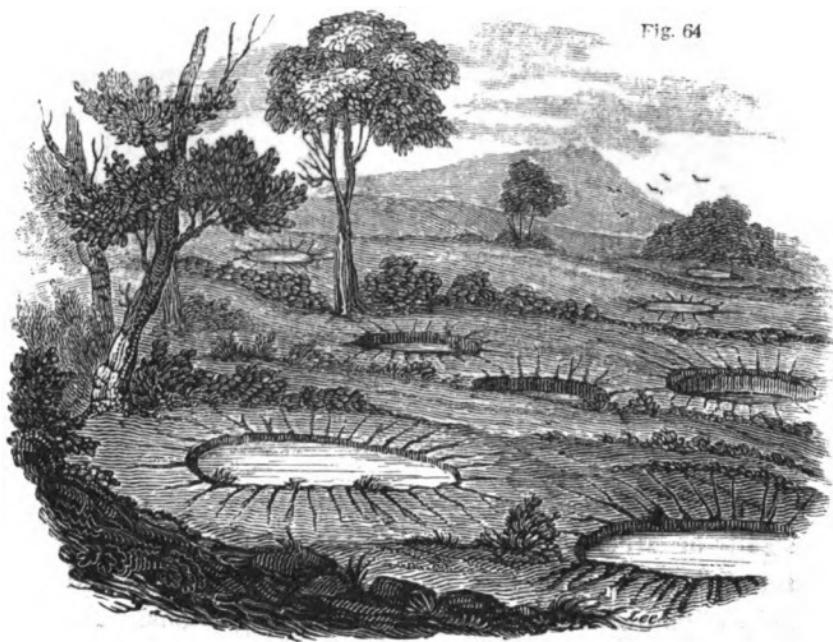
was greatly convulsed, various portions of soil being raised or sunk, and innumerable fissures traversing the country in all directions (see Fig. 63.). Along the flanks of a small valley in this district there appears to have been an almost uninterrupted line of landslips.

Number of new-formed lakes. — Vivenzio states, that near Sitizzano a valley was nearly filled up to a level with the high grounds on each side, by the enormous masses detached from the boundary hills, and cast down into the course of two streams. By this barrier a lake was formed of great depth, about two miles long and a mile broad. The same author mentions that, upon the whole, there were fifty lakes occasioned during the convulsions: and he assigns localities to all of these. The government surveyors enumerated 215 lakes, but they included in this number many small ponds.

Currents of mud. — Near S. Lucido, among other places, the soil is described as having been "dissolved," so that large torrents of mud inundated all the low grounds, like lava. Just emerging from this mud, the tops only of trees and of the ruins of farm-houses were seen. Two miles from Laureana, the swampy soil in two ravines became filled with calcareous matter, which oozed out from the ground immediately before the first great shock. This mud, rapidly accumulating, began, ere long, to roll onward, like a flood of lava, into the valley, where the two streams uniting, moved forward with increased impetus from east to west. It now presented a breadth of 225 feet by fifteen in depth, and, before it ceased to move, covered a surface equal in length to an Italian mile. In its progress it overwhelmed a flock of thirty goats, and tore up by the roots many olive and mulberry-trees, which floated like ships upon its surface. When this calcareous lava had ceased to move, it gradually became dry and hard, during which process the mass was lowered seven feet and a half. It contained fragments of earth of a ferruginous colour, and emitting a sulphureous smell.

Cones of sand thrown up. — Many of the appearances exhibited in the alluvial plains indicate clearly the alternate rising and sinking of the ground. The first effect of the more violent shocks was usually to dry up the rivers, but they immediately afterwards overflowed their banks. Along the alluvial plains, and in marshy places, an immense number of cones of sand were thrown up. These appearances Hamilton explains, by supposing that the first movement raised the fissured plain from below upwards, so that the rivers and stagnant waters in bogs sank down, or at least were not upraised with the soil. But when the ground returned with violence to its former position, the water was thrown up in jets through fissures.*

Fig. 64

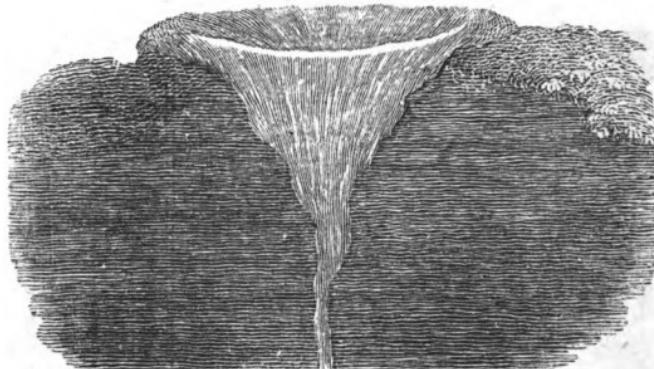


Circular hollows in the plain of Rosarno, formed by the earthquake of 1783.

* Phil. Trans. vol. lxxiii. p. 180.

Formation of circular hollows.—In the report of the Academy, we find that some plains were covered with circular hollows, for the most part about the size of carriage-wheels, but often somewhat larger or smaller. When filled with water to within a foot or two of the surface, they appeared like wells; but, in general, they were filled with dry sand, sometimes with a concave surface, and at other times convex. (See Fig. 64.) On digging down, they found them to be funnel-shaped, and the moist loose sand in the centre marked the tube up which the water spouted. The annexed cut (Fig. 65.) represents a section of one of these inverted cones when the water had disappeared, and nothing but dry micaceous sand remained.

Fig. 65.



Section of one of the circular hollows formed in the plain of Rosarno.

Fall of the sea cliffs.—Along the sea-coast of the straits of Messina, near the celebrated rock of Scilla, the fall of huge masses detached from the bold and lofty cliffs overwhelmed many villas and gardens. At Gian Greco, a continuous line of cliff, for a mile in length, was thrown down. Great agitation was frequently observed in the bed of the sea during the

shocks, and, on those parts of the coast where the movement was most violent, all kinds of fish were taken in abundance, and with unusual facility. Some rare species, as that called Cicirelli, which usually lie buried in the sand, were taken on the surface of the waters in great quantity. The sea is said to have boiled up near Messina, and to have been agitated as if by a copious discharge of vapours from its bottom.

Shore near Scilla inundated. — The Prince of Scilla had persuaded a great part of his vassals to betake themselves to their fishing-boats for safety, and he himself had gone on board. On the night of the 5th of February, when some of the people were sleeping in the boats, and others on a level plain slightly elevated above the sea, the earth rocked, and suddenly a great mass was torn from the contiguous Mount Jaci, and thrown down with a dreadful crash upon the plain. Immediately afterwards, the sea, rising more than twenty feet above the level of this low tract, rolled foaming over it, and swept away the multitude. It then retreated, but soon rushed back again with greater violence, bringing with it some of the people and animals it had carried away. At the same time every boat was sunk or dashed against the beach, and some of them were swept far inland. The aged prince, with 1430 of his people, was destroyed.

State of Stromboli and Etna during the shocks. — The inhabitants of Pizzo remarked that, on the 5th of February, 1783, when the first great shock afflicted Calabria, the volcano of Stromboli, which is in full view of that town, and at the distance of about fifty miles, smoked less, and threw up a less quantity of inflamed matter, than it had done for some years previously. On the other hand, the great crater of Etna

is said to have given out a considerable quantity of vapour towards the beginning, and Stromboli towards the close, of the commotions. But as no eruption happened from either of these great vents during the whole earthquake, the sources of the Calabrian convulsions, and of the volcanic fires of Etna and Stromboli, appear to be very independent of each other; unless, indeed, they have the same mutual relation as Vesuvius and the volcanos of the Phlegræan Fields and Ischia, a violent disturbance in one district serving as a safety-valve to the other, and both never being in full activity at once.

Excavation of valleys. — It is impossible for the geologist to consider attentively the effect of this single earthquake of 1783, and to look forward to the alterations in the physical condition of the country to which a continued series of such movements will hereafter give rise, without perceiving that the formation of valleys by running water can never be understood, if we consider the question independently of the agency of earthquakes. It must not be imagined that rivers only begin to act when a country is already elevated far above the level of the sea, for their action must of necessity be most powerful while land is *rising* or *sinking* by successive movements. Whether Calabria is now undergoing any considerable change of relative level, in regard to the sea, or is, upon the whole, nearly stationary, is a question which our observations, confined almost entirely to the last half century, cannot possibly enable us to determine. But we know that strata, containing species of shells identical with those now living in the contiguous parts of the Mediterranean, have been raised in that country, as they have in Sicily, to the height of several thousand feet.

Now, those geologists who grant that the present course of Nature in the inanimate world has continued the same since the existing species of animals were in being, will not feel surprise that the Calabrian streams and rivers have cut out of such comparatively modern strata a great system of valleys, varying in depth from fifty to six hundred feet, and often several miles wide, if they consider how numerous must have been the earthquakes which lifted those recent marine strata to so prodigious a height. Some speculators, indeed, who disregard the analogy of existing Nature, and who are always ready to assume that her forces were more energetic in by-gone ages, may dispense with a long series of movements, and suppose that Calabria "rose like an exhalation" from the deep, after the manner of Milton's Pandemonium. But such an hypothesis would deprive them of that peculiar removing force required to form a regular system of deep and wide valleys; for *time*, which they are so unwilling to assume, is essential to the operation. Time must be allowed in the intervals between distinct convulsions, for running water to clear away the ruins caused by landslips, otherwise the fallen masses will serve as buttresses, and prevent the succeeding earthquake from exerting its full power. The sides of the valley must be again cut away by the stream, and made to form precipices and overhanging cliffs, before the next shock can take effect in the same manner.

Possibly the direction of the succeeding shock may not coincide with that of the valley, a great extent of adjacent country being equally shaken. Still it will usually happen that no permanent geographical change will be produced except in valleys. In them alone will occur landslips from the boundary cliffs, and these will

frequently divert the stream from its accustomed course, causing the original ravine to become both wider and more tortuous in its direction.

If a single convulsion of extreme violence should agitate at once an entire hydrographical basin, or if the shocks should follow each other too rapidly, the previously existing valleys would be annihilated, instead of being modified and enlarged. Every stream might in that case be compelled to begin its operations anew, and to shape out new channels, instead of continuing to deepen and widen those already excavated. But if the subterranean movements have been intermittent ; and if sufficient periods have always intervened between the severer shocks to allow the drainage of the country to be nearly restored to its original state, then are both the kind and degree of force supplied by which running water may hollow out valleys of any depth or size consistent with the elevation above the sea which the districts drained by them may have attained.

When we read of the drying up and desertion of the channels of rivers, the accounts most frequently refer to their deflection into some other part of the same alluvial plain, perhaps several miles distant. Under certain circumstances, a change of level may undoubtedly force the water to flow over into some distinct hydrographical basin ; but even then it will fall immediately into some other system of valleys already formed.

We learn from history that, ever since the first Greek colonists settled in Calabria, that region has been subject to devastation by earthquakes ; and, for the last century and a half, ten years have seldom elapsed without a shock ; but the severer convulsions have not only been separated by intervals of twenty,

fifty, or one hundred years ; but have not affected precisely the same points when they recurred. Thus the earthquake of 1783, although confined within the same geographical limits as that of 1638, and not very inferior in violence, visited, according to Grimaldi, very different districts. The points where the local intensity of the force is developed being thus perpetually varied, more time is allowed, for the removal of separate mountain masses thrown into river channels by each shock.

Number of persons who perished during the earthquake. — The number of persons who perished during the earthquake in the two Calabrias and Sicily is estimated by Hamilton at about forty thousand, and about twenty thousand more died by epidemics, which were caused by insufficient nourishment, exposure to the atmosphere, and malaria, arising from the new stagnant lakes and pools.

By far the greater number were buried under the ruins of their houses ; but many were burnt to death in the conflagrations which almost invariably followed the shocks. These fires raged the more violently in some cities, such as Oppido, from the immense magazines of oil which were consumed.

Many persons were engulfed in deep fissures, especially the peasants, when flying across the open country, and their skeletons may perhaps be buried in the earth to this day, at the depth of several hundred feet.

When Dolomieu visited Messina after the shock of Feb. 5th, he describes the city as still presenting, at least at a distance, an imperfect image of its ancient splendour. Every house was injured, but the walls were standing : the whole population had taken refuge

in wooden huts in the neighbourhood, and all was solitude and silence in the streets : it seemed as if the city had been desolated by the plague, and the impression made upon his feelings was that of melancholy and sadness. “ But when I passed over to Calabria, and first beheld Polistena, the scene of horror almost deprived me of my faculties ; my mind was filled with mingled compassion and terror ; nothing had escaped ; all was levelled with the dust ; not a single house or piece of wall remained ; on all sides were heaps of stone so destitute of form, that they gave no conception of there ever having been a town on the spot. The stench of the dead bodies still rose from the ruins. I conversed with many persons who had been buried for three, four, and even for five days : I questioned them respecting their sensations in so dreadful a situation, and they agreed that, of all the physical evils they endured, thirst was the most intolerable ; and that their mental agony was increased by the idea that they were abandoned by their friends, who might have rendered them assistance.” *

It is supposed that about a fourth part of the inhabitants of Polistena, and of some other towns, were buried alive, and might have been saved had there been no want of hands ; but in so general a calamity, where each was occupied with his own misfortunes, or those of his family, aid could rarely be obtained. Neither tears, nor supplications, nor promises of high rewards were listened to. Many acts of self-devotion, prompted by parental and conjugal tenderness, or by friendship, or the gratitude of faithful servants, are recorded ; but individual exertions were, for the most

* Dissertation on the Calabrian Earthquakes, &c. translated in Pinkerton’s Voyages and Travels, vol. v.

part, ineffectual. It frequently happened, that persons in search of those most dear to them could hear their moans, — could recognize their voices, — were certain of the exact spot where they lay buried beneath their feet, yet could afford them no succour. The piled mass resisted all their strength, and rendered their efforts of no avail.

At Terranuova, four Augustin monks, who had taken refuge in a vaulted sacristy, the arch of which continued to support an immense pile of ruins, made their cries heard for the space of four days. One only of the brethren of the whole convent was saved, and “of what avail was his strength to remove the enormous weight of rubbish which had overwhelmed his companions ?” He heard their voices die away gradually ; and when afterwards their four corpses were disinterred, they were found clasped in each other’s arms. Affecting narratives are preserved of mothers saved after the fifth, sixth, and even seventh day of their interment, when their infants or children had perished with hunger.

It might have been imagined that the sight of sufferings such as these would have been sufficient to awaken sentiments of humanity and pity in the most savage breasts, but while some acts of heroism are related, nothing could exceed the general atrocity of conduct displayed by the Calabrian peasants : they abandoned the farms, and flocked in great numbers into the towns — not to rescue their countrymen from a lingering death, but to plunder. They dashed through the streets, fearless of danger, amid tottering walls and clouds of dust, trampling beneath their feet the bodies of the wounded and half buried, and often stripping them, while yet living, of their clothes.*

* Dolomieu, *ibid.*

Concluding remarks. — But to enter more fully into these details would be foreign to the purpose of the present work, and several volumes would be required to give the reader a just idea of the sufferings which the inhabitants of many populous districts have undergone during the earthquakes of the last 150 years. A bare mention of the loss of life — as that fifty or a hundred thousand souls perished in one catastrophe — conveys to the reader no idea of the extent of misery inflicted: we must learn, from the narratives of eye-witnesses, the various forms in which death was encountered, the numbers who escaped with loss of limbs or serious bodily injuries, and the multitude who were suddenly reduced to penury and want. It has been often remarked, that the dread of earthquakes is strongest in the minds of those who have experienced them most frequently; whereas, in the case of almost every other danger, familiarity with peril renders men intrepid. The reason is obvious — scarcely any part of the mischief apprehended in this instance is imaginary; the first shock is often the most destructive; and, as it may occur in the dead of the night, or if by day, without giving the least warning of its approach, no forethought can guard against it; and when the convulsion has begun, no skill, or courage, or presence of mind, can point out the path of safety. During the intervals, of uncertain duration, between the more fatal shocks, slight tremors of the soil are not unfrequent; and as these sometimes precede more violent convulsions, they become a source of anxiety and alarm. The terror arising from this cause alone is of itself no inconsiderable evil.

Although sentiments of pure religion are frequently awakened by these awful visitations, yet we more

commonly find that an habitual state of fear, a sense of helplessness, and a belief in the futility of all human exertions, prepare the minds of the vulgar for the influence of a demoralizing superstition.

Where earthquakes are frequent, there can never be perfect security of property under the best government; industry cannot be assured of reaping the fruits of its labour; and the most daring acts of outrage may occasionally be perpetrated with impunity, when the arm of the law is paralysed by the general consternation. It is hardly necessary to add, that the progress of civilization and national wealth must be retarded by convulsions which level cities to the ground, destroy harbours, render roads impassable, and cause the most cultivated valley-plains to be covered with lakes, or the ruins of adjoining hills.

Those geologists who imagine that, at remote periods ere man became a sojourner on earth, the volcanic agency was more energetic than now, should be careful to found their opinion on strict geological evidence, and not permit themselves to be biassed, as they have often been, by a notion, that the disturbing force would probably be mitigated for the sake of man.

I shall endeavour to point out in the sequel, that the general tendency of subterranean movements, when their effects are considered for a sufficient lapse of ages, is eminently beneficial, and that they constitute an essential part of that mechanism by which the integrity of the habitable surface is preserved, and the very existence and perpetuation of dry land secured. Why the working of this same machinery should be attended with so much evil, is a mystery far beyond the reach of our philosophy, and must probably remain so until we are permitted to investigate, not our

planet alone and its inhabitants, but other parts of the moral and material universe with which they may be connected. Could our survey embrace other worlds, and the events, not of a few centuries only, but of periods as indefinite as those with which geology renders us familiar, some apparent contradictions might be reconciled, and some difficulties would doubtless be cleared up. But even then, as our capacities are finite, while the scheme of the universe may be infinite, both in time and space, it is presumptuous to suppose that all sources of doubt and perplexity would ever be removed. On the contrary, they might, perhaps, go on augmenting in number ; for it has been justly said, that the greater the circle of light, the greater the boundary of darkness by which it is surrounded.*

* Sir H. Davy's Consolations in Travel, p. 246.

CHAPTER XVII.

EARTHQUAKES OF THE EIGHTEENTH CENTURY — *continued.*

Earthquake of Guatemala, 1773 — Java, 1772 — Truncation of a lofty cone — St. Domingo, 1770 — Colombia, 1766 — Lisbon, 1755 — Shocks felt throughout Europe, Northern Africa, and the West Indies — Great wave — Conception Bay, 1750 — Permanent elevation — Peru, 1746 — Kamtschatka, 1737 — Java, 1699 — Rivers obstructed by landslips — Subsidence in Sicily, 1693 — Moluccas, 1693 — Jamaica, 1692 — Large tracts engulfed — Portion of Port Royal sunk — Amount of change in the last 150 years — Elevation and subsidence of land in Bay of Baiæ — Evidence of the same afforded by the Temple of Serapis.

In the preceding chapters we have considered a small part of those earthquakes only which have occurred during the last sixty years, of which accurate and authentic descriptions happen to have been recorded. We may next proceed to examine some of earlier date, respecting which information of geological interest has been obtained.

Central America, June, 1773. — The town of Guatemala was founded, in 1742, on the side of a volcano, in a valley about three miles wide, opening to the South Sea; nine years afterwards it was destroyed by an earthquake, and again, in 1773, during an eruption of the volcano. The ground on which the town stood gaped open in deep fissures, until at length, after five days, the city, with all its riches, and eight thousand

families, is said to have been swallowed up in an abyss.* This account, however, must have been exaggerated, for the mouldering ruins of the old town are described by Mr. E. L. Page as existing in 1834. It was abandoned for many years, but has now been repeopled with 12,000 inhabitants; the new city, at the distance of about four leagues, having already acquired a population of about 40,000 persons.† This place also suffered by an earthquake in April, 1830.

Java, 1772.—Truncation of a lofty cone. — In the year 1772, Papandayang, formerly one of the loftiest volcanos in the island of Java, was in eruption. Before all the inhabitants on the declivities of the mountain could save themselves by flight, the ground began to give way, and a great part of the volcano fell in and disappeared. It is estimated that an extent of ground of the mountain itself and its immediate environs, fifteen miles long and full six broad, was by this commotion swallowed up in the bowels of the earth. Forty villages were destroyed, some being engulfed and some covered by the substances thrown out on this occasion, and 2957 of the inhabitants perished. A proportionate number of cattle were also killed, and most of the plantations of cotton, indigo, and coffee in the adjacent districts were buried under the volcanic matter. This catastrophe appears to have resembled, although on a grander scale, that of the ancient Vesuvius in the year 79. The cone was reduced in height from nine thousand to about five thousand feet; and, as vapours still escape from the crater on its summit, a new cone may one day rise out of the ruins of the

* Dodsley's Ann. Regist. vol. xvi. p. 149.

† Geographical Journal, vol. viii. p. 321.

ancient mountain, as the modern Vesuvius has risen from the remains of Somma.*

Caucasus, 1772. — About the year 1772, an earthquake convulsed the ground in the province at Beshtau, in the Caucasus, so that part of the hill Metshuka sunk into an abyss.†

St. Domingo, 1770. — During a tremendous earthquake which destroyed a great part of St. Domingo, innumerable fissures were caused throughout the island, from which mephitic vapours emanated and produced an epidemic. *Hot springs* burst forth in many places where there had been no water before ; but after a time they ceased to flow.‡

Colombia, 1766. — On the 21st of October, 1766, the ground was agitated at once at Cumana, at Caracas, at Maraycabo, and on the banks of the rivers Casanare, the Meta, the Orinoco, and the Ventuario. These districts were much fissured, and great fallings in of the earth took place in the mountain Paurari : Trinidad was violently shaken. A small island in the Orinoco, near the rock Aravacoto, sunk down and disappeared.§ At the same time the ground was raised in the sea near Cariaco, where the Point Del Gardo was enlarged. A rock also rose up in the river

* Dr. Horsfield, Batav. Trans. vol. viii. p. 26. Dr. H. informs me that he has seen this truncated mountain : and, though he did not ascend it, he has conversed with those who have examined it. Raffles's account (*History of Java*, vol. i.) is derived from Horsfield.

† Pallas's Travels in Southern Russia.

‡ Essai sur l'Hist. Nat. de l'Isle de St. Domingue. Paris, 1776.

§ Humboldt's Personal Narrative, vol. iv. p. 45. ; and Saggio di Storia Americana, vol. ii. p. 6.

Guarapica, near the village of Maturin.* The shocks continued in Colombia hourly for fourteen months.

Hindostan, 1762.—The town of Chittagong, in Bengal, was violently shaken by an earthquake, on the 2d of April, 1762, the earth opening in many places, and throwing up water and mud of a sulphureous smell. At a place called Bardavan a large river was dried up; and at Bar Charra, near the sea, a tract of ground sunk down, and 200 people, with all their cattle, were lost. It is said, that sixty square miles of the Chittagong coast suddenly and permanently subsided during this earthquake, and that Ces-lung-Toom, one of the Mug mountains, entirely disappeared, and another sank so low, that its summit only remained visible. Four hills are also described as having been variously rent asunder, leaving open chasms from thirty to sixty feet in width. Towns which subsided several cubits were overflowed with water; among others, Deep Gong, which was submerged to the depth of seven cubits. Two volcanos are said to have opened in the Secta-Cunda hills. The shock was also felt at Calcutta.†

Lisbon, 1755.—In no part of the volcanic region of southern Europe has so tremendous an earthquake occurred in modern times as that which began on the 1st of November, 1755, at Lisbon. A sound of thunder was heard underground, and immediately afterwards a violent shock threw down the greater part of that city. In the course of about six minutes, sixty thousand persons perished. The sea first retired

* Humboldt, *Voy. Relat. Hist.*, part i. p. 307. ; and part ii. p. 23.

† M'Clelland's *Report on Min. Resources of India*, 1838. Calcutta. For other particulars, see *Phil. Trans.* vol. liii.

and laid the bar dry ; it then rolled in, rising fifty feet or more above its ordinary level. The mountains of Arrabida, Estrella, Julio, Marvan, and Cintra, being some of the largest in Portugal, were impetuously shaken, as it were, from their very foundations ; and some of them opened at their summits, which were split and rent in a wonderful manner, huge masses of them being thrown down into the subjacent valleys.* Flames are related to have issued from these mountains, which are supposed to have been electric ; they are also said to have smoked ; but vast clouds of dust may have given rise to this appearance.

Subsidence of the quay. — The most extraordinary circumstance which occurred at Lisbon during the catastrophe was the subsidence of a new quay, built entirely of marble at an immense expense. A great concourse of people had collected there for safety, as a spot where they might be beyond the reach of falling ruins ; but, suddenly, the quay sank down with all the people on it, and not one of the dead bodies ever floated to the surface. A great number of boats and small vessels anchored near it, all full of people, were swallowed up, as in a whirlpool.† No fragments of these wrecks ever rose again to the surface, and the water in the place where the quay had stood is stated, in many accounts, to be unfathomable ; but Whitehurst says, he ascertained it to be one hundred fathoms.‡

In this case, we must either suppose that a certain tract sank down into a subterranean hollow, which

* Hist and Philos. of Earthquakes, p. 317.

† Rev. C. Davy's Letters, vol. ii. Letter ii. p. 12., who was at Lisbon at the time, and ascertained that the boats and vessels said to have been swallowed were missing.

‡ On the Formation of the Earth, p. 55.

would cause a “fault” in the strata to the depth of six hundred feet, or we may infer, as some have done, from the entire disappearance of the substances engulfed, that a chasm opened and closed again. Yet, in adopting this latter hypothesis, we must suppose that the upper part of the chasm, to the depth of one hundred fathoms remained open after the shock. According to the observations made at Lisbon, in 1837, by Mr. Sharpe, the destroying effects of this earthquake were confined to the tertiary strata, and were most violent on the blue clay, on which the lower part of the city is constructed. Not a building, he says, on the secondary limestone or the basalt was injured.*

Area over which the earthquake extended. — The great area over which this Lisbon earthquake extended is very remarkable. The movement was most violent in Spain, Portugal, and the north of Africa; but nearly the whole of Europe, and even the West Indies, felt the shock on the same day. A seaport, called St. Ubes, about twenty miles south of Lisbon, was engulfed. At Algiers and Fez, in Africa, the agitation of the earth was equally violent; and at the distance of eight leagues from Morocco, a village with the inhabitants, to the number of about eight or ten thousand persons, together with all their cattle, were swallowed up. Soon after the earth closed again over them.

Shocks felt at sea. — The shock was felt at sea, on the deck of a ship to the west of Lisbon, and produced very much the same sensation as on dry land. Off St. Lucar, the captain of the ship Nancy felt his vessel so violently shaken, that he thought she had struck the ground; but, on heaving the lead, found a great depth

* Geol. Soc. Proceedings, No. 60. p. 36. 1838.

of water. Captain Clark, from Denia, in latitude $36^{\circ} 24'$ N., between nine and ten in the morning, had his ship shaken and strained as if she had struck upon a rock, so that the seams of the deck opened, and the compass was overturned in the binnacle. Another ship, forty leagues west of St. Vincent, experienced so violent a concussion, that the men were thrown a foot and a half perpendicularly up from the deck. In Antigua and Barbadoes, as also in Norway, Sweden, Germany, Holland, Corsica, Switzerland, and Italy, tremors and slight oscillations of the ground were felt.

Rate at which the movement travelled.—The agitation of lakes, rivers, and springs, in Great Britain, was remarkable. At Loch Lomond, in Scotland, for example, the water, without the least apparent cause, rose against its banks, and then subsided below its usual level. The greatest perpendicular height of this swell was two feet four inches. It is said that the movement of this earthquake was undulatory, and that it travelled at the rate of twenty miles a minute, its velocity being calculated by the intervals between the time when the first shock was felt at Lisbon and its time of occurrence at other distant places.*

Great wave and retreat of the sea.—A great wave swept over the coast of Spain, and is said to have been sixty feet high at Cadiz. At Tangier, in Africa, it rose and fell eighteen times on the coast. At Funchal, in Madeira, it rose full fifteen feet perpendicular above high-water mark, although the tide, which ebbs and flows there seven feet, was then at half ebb. Besides entering the city, and committing great havoc,

* Michell on the Cause and Phenomena of Earthquakes, Phil. Trans. vol. li. p. 566. 1760.

it overflowed other seaports in the island. At Kinsale, in Ireland, a body of water rushed into the harbour, whirled round several vessels, and poured into the market-place.

It was before stated that the sea first retired at Lisbon ; and this retreat of the ocean from the shore, at the commencement of an earthquake and its subsequent return in a violent wave, is a common occurrence. In order to account for the phenomenon, Michell imagined a subsidence at the bottom of the sea, from the giving way of the roof of some cavity in consequence of a vacuum produced by the condensation of steam. Such condensation, he observes, might be the first effect of the introduction of a large body of water into fissures and cavities already filled with steam, before there has been sufficient time for the heat of the incandescent lava to turn so large a supply of water into steam, which being soon accomplished causes a greater explosion.

Another proposed explanation is, the sudden rise of the land, which would cause the sea to abandon immediately the ancient line of coast ; and if the shore, after being thus heaved up, should fall again to its original level, the ocean would return. This theory, however, will not account for the facts observed during the Lisbon earthquake ; for the retreat preceded the wave, not only on the coast of Portugal, but also at the island of Madeira, and several other places. If the upheaving of the coast of Portugal had caused the retreat, the motion of the waters, when propagated to Madeira, would have produced a wave previous to the retreat. Nor could the motion of the waters at Madeira have been caused by a different local earthquake ; for the shock travelled from Lisbon to Madeira in two

hours, which agrees with the time which it required to reach other places equally distant.*

The following is another solution of the problem, which has been offered:— Suppose a portion of the bed of the sea to be suddenly upheaved, the first effect will be to raise over the elevated part a body of water, the momentum of which will carry it much above the level it will afterwards assume, causing a draught or receding of the water from the neighbouring coasts, followed immediately by the return of the displaced water, which will also be impelled by its momentum much farther and higher on the coast than its former level.†

Mr. Darwin, when alluding to similar waves on the coast of Chili, states his opinion, that “the whole phenomenon is due to a common undulation in the water, proceeding from a line or point of disturbance some little way distant. If the waves,” he says, “sent off from the paddles of a steam vessel be watched breaking on the sloping shore of a still river, the water will be seen first to retire two or three feet, and then to return in little breakers, precisely analogous to those consequent on an earthquake.” He also adds, that “the earthquake wave occurs some time after the shock, the water at first retiring both from the shores of the mainland and of outlying islands, and then returning in mountainous breakers. Their size is modified by the form of the neighbouring coast; for it is ascertained in South America, that places situated at the head of shoaling bays have suffered most, whereas towns like Valparaiso, seated close on the border of a

* Michell, Phil. Trans. vol. li. p. 614.

† Quarterly Review, No. lxxxvi. p. 459.

profound ocean, have never been inundated, though severely shaken by earthquakes.”*

St. Domingo, 1751. — On the 15th of September, 1751, an earthquake began in several of the West India Islands; and on the 21st of November, a violent shock destroyed the capital of St. Domingo, Port au Prince. Part of the coast, twenty leagues in length, sank down, and has ever since formed a bay of the sea.†

Chili, 1751. — On the 24th of May, 1751, the ancient town of Conception, otherwise called Penco, was totally destroyed by an earthquake, and the sea rolled over it. (See plan of the bay, Fig. 52. p. 298.) The ancient port was rendered entirely useless, and the inhabitants built another town about ten miles from the sea-coast, in order to be beyond the reach of similar inundations. At the same time, a colony recently settled on the sea-shore of Juan Fernandez was almost entirely overwhelmed by a wave which broke upon the shore.

It has been already stated, that in 1835, or eighty-four years after the destruction of Penco, the same coast was overwhelmed by a similar flood from the sea during an earthquake; and it is also known, that twenty-one years before (or in 1730), a like wave rolled over these fated shores, in which many of the inhabitants perished. A series of similar catastrophes has also been traced back as far as the year 1590‡, beyond which we have no memorials save those of oral

* Darwin’s Travels in South America, &c. 1832 to 1836. Voyage of H. M. S. Beagle, vol. iii. p. 977.

† Hist. de l’Acad. des Sciences. 1752. Paris.

‡ See Father Acosta’s work; and Sir Woodbine Parish, Geol. Soc. Proceedings, vol. ii. p. 215.

tradition. Molina, who has recorded the customs and legends of the aborigines, tells us, that the Araucanian Indians, a tribe inhabiting the country between the Andes and Pacific, including the part now called Chili, "had among them a tradition of a great deluge, in which only a few persons were saved, who took refuge upon a high mountain called Thegtheg, "the thundering," which had three points. Whenever a violent earthquake occurs, these people fly for safety to the mountains, assigning as a reason, that they are fearful, after the shock, that the sea will again return and deluge the world." *

Notwithstanding the tendency of writers in his day to refer all traditional inundations to one remote period, Molina remarks that this flood of the Araucanians "was probably very different from that of Noah." We have, indeed, no means of conjecturing how long this same tribe had flourished in Chili, but we can scarcely doubt, that if its experience reached back even for three or four centuries, several inroads of the ocean must have occurred within that period. But the memory of a succession of physical events, similar in kind, though distinct in time, can never be preserved by a people destitute of written annals. Before two or three generations have passed away all dates are forgotten, and even the events themselves, unless they have given origin to some customs, or religious rites and ceremonies. Oftentimes the incidents of many different earthquakes and floods become blended together in the same narrative; and in such cases the single catastrophe is described in terms

* Molina, Hist. of Chili, vol. ii. p. 93.

so exaggerated, or is so disguised by mythological fictions, as to be utterly valueless to the antiquary or philosopher.

Proofs of elevation of twenty-four feet.—During a late survey of Conception Bay, Captains Beechey and Belcher discovered that the ancient harbour, which formerly admitted all large merchant vessels which went round the Cape, is now occupied by a reef of sandstone, certain points of which project above the sea at low water, the greater part being very shallow. A tract of a mile and a half in length, where, according to the report of the inhabitants, the water was formerly four or five fathoms deep, is now a shoal ; consisting, as our hydrographers found, of hard sand-stone, so that it cannot be supposed to have been formed by recent deposits of the river Biobio, an arm of which carries down loose micaceous sand into the same bay.

It is impossible at this distance of time to affirm that the bed of the sea was uplifted at once to the height of twenty-four feet, during the single earthquake of 1751, because other movements may have occurred subsequently ; but it is said, that ever since the shock of 1751, no vessels have been able to approach within a mile and a half of the ancient port of Penco. (See Map, p. 298.) In proof of the former elevation of the coast near Penco our surveyors found above high-water mark an enormous bed of shells of the same species as those now living in the bay, filled with micaceous sand like that which the Biobio now conveys to the bay. These shells, as well as others, which cover the adjoining hills of mica-schist to the height of several hundred feet, have lately been examined by experienced conchologists in London, and identified

with those taken at the same time in a living state from the bay and its neighbourhood.*

Ulloa, therefore, was perfectly correct in his statement that, at various heights above the sea between Talcahuano and Conception, "mines were found of various sorts of shells used for lime of the very same kinds as those found in the adjoining sea." Among them he mentions the great mussel called Choros, and two others which he describes. Some of these, he says, are entire, and others broken; they occur at the bottom of the sea, in four, six, ten, or twelve fathom water, where they adhere to a sea-plant called Cochayuyo. They are taken in dredges, and have no resemblance to those found on the shore or in shallow water; yet beds of them occur at various heights on the hills. "I was the more pleased with the sight," he adds, "as it appeared to me a convincing proof of the universality of the deluge, although I am not ignorant that some have attributed their position to other causes."† It has, however, been asserted that the foundation of the Castle of Penco was so low in 1835, or at so inconsiderable an elevation above the highest spring tides, as to discountenance the idea of any permanent upheaval in modern times, on the site of that ancient port; but no exact measurements or levellings appear as yet to have been made to determine this point, which is the more worthy of investigation, because it may throw some light on an opinion often promulgated of late years, that there is a tendency in the Chilian coast, after each upheaval, to sink gradually and return towards its former position.

* Captain Belcher has shown me these shells, and the collection has been examined by Mr. Broderip.

† Ulloa's Voyage to South America, vol. ii, book viii. ch. vi.

Peru, 1746.—Peru was visited, on the 28th of October, 1746, by a tremendous earthquake. In the first twenty-four hours, two hundred shocks were experienced. The ocean twice retired and returned impetuously upon the land: Lima was destroyed, and part of the coast near Callao was converted into a bay: four other harbours, among which were Cavalla and Guanape, shared the same fate. There were twenty-three ships and vessels, great and small, in the harbour of Callao, of which nineteen were sunk; and the other four, among which was a frigate called St. Fermin, were carried by the force of the waves to a great distance up the country, and left on dry ground at considerable heights above the sea. The number of inhabitants in this city amounted to four thousand. Two hundred only escaped, twenty-two of whom were saved on a small fragment of the fort of Vera Cruz, which remained as the only memorial of the town after this dreadful inundation. Other portions of its site were completely covered with heaps of sand and gravel.

A volcano in Lucanas burst forth the same night, and such quantities of water descended from the cone that the whole country was overflowed; and in the mountain near Pataz, called Conversiones de Caxamarquilla, three other volcanos burst out, and frightful torrents of water swept down their sides.*

There are several records of prior convulsions in Peru, accompanied by similar inroads of the sea, one of which happened fifty-nine years before (in 1687), when the ocean, according to Ulloa, first retired and then returned in a mountainous wave, overwhelming Callao and its environs with the miserable inhabitants.†

* Ulloa's *Voyage*, vol. ii. book vii. chap. vii.

† *Ibid.* vol. ii. p. 82.

This same wave, according to Lionel Wafer, carried ships a league into the country, and drowned man and beast for fifty leagues along the shore.* Inundations of still earlier dates are carefully recorded by Ulloa, Wafer, Acosta, and various writers, who describe them as having expended their chief fury some on one part of the coast some on another.

But all authentic accounts cease when we ascend to the era of the conquest of Peru by the Spaniards. The ancient Peruvians, although far removed from barbarism, were without written annals, and therefore unable to preserve a distinct recollection of a long series of natural events. They had, however, according to Antonio de Herrera, who, in the beginning of the seventeenth century investigated their antiquities, a tradition, "that many years before the reign of the Incas, at a time when the country was very populous, there happened a great flood; the sea breaking out beyond its bounds, so that the land was covered with water, and all the people perished. To this the Guacas, inhabiting the vale of Xausca, and the natives of Chiquito, in the province of Callao, add that some persons remained in the hollows and caves of the highest mountains, who again peopled the land. Others of the mountain people affirm that all perished in the deluge, only six persons being saved on a float, from whom descended all the inhabitants of that country."†

On the mainland near Lima, and on the neighbouring island of San Lorenzo, Mr. Darwin found proofs that the ancient bed of the sea had been raised to the

* Wafer, cited by Sir W. Parish, Geol. Soc. Proceedings, v. ii. p. 215.

† Hist. of America, decad. iii. book xi. chap. i.

height of more than eighty feet above water within the human epoch, strata having been discovered at that altitude, containing pieces of cotton-thread and plaited rush, together with sea-weed and marine shells.* The same author learnt from Mr. Gill, a civil engineer, that he discovered in the interior, near Lima, between Casma and Huaraz, the dried-up channel of a large river, sometimes worn through solid rock, which, instead of continually ascending towards its source, has, in one place, a steep downward slope in that direction, for a ridge or line of hills has been uplifted directly across the bed of the stream, which is now arched. By these changes the water has been turned into some other course; and a district, once fertile, and still covered with ruins, and bearing the marks of ancient cultivation, has been converted into a desert.†

Kamtschatha, 1737, &c.—There are records of earthquakes in Kamtschatka and the Kurile Isles, in 1737,—in Martinique, in 1727,—Iceland, 1725,—Teneriffe, 1706,—during which the shape of the ground both above and beneath the level of the sea was greatly changed.

Java, 1699.—On the 5th of January, 1699, a terrible earthquake visited Java, and no less than 208 considerable shocks were reckoned. Many houses in Batavia were overturned, and the flame and noise of a volcanic eruption were seen and heard in that city, which were afterwards found to proceed from Mount Salak‡, a volcano six days' journey distant. Next morning the Batavian river, which has its rise from that mountain, became very high and muddy, and brought down abundance of bushes and trees, half

* Darwin's Journal, p. 451.

† Ibid. p. 413.

‡ Misspelt Sales in Hooke's Account.

burnt. The channel of the river being stopped up, the water overflowed the country round the gardens about the town, and some of the streets, so that fishes lay dead in them. All the fish in the river, except the carps, were killed by the mud and turbid water. A great number of drowned buffaloes, tigers, rhinoceroses, deer, apes, and other wild beasts, were brought down by the current ; and, " notwithstanding," observes one of the writers, " that a crocodile is amphibious, several of them were found dead among the rest."*

It is stated, that seven hills bounding the river sank down ; by which is merely meant, as by similar expressions in the description of the Calabrian earthquakes, seven great landslips. These hills, descending some from one side of the valley and some from the other, filled the channel, and the waters then finding their way under the mass, flowed out thick and muddy. The Tangaran river was also dammed up by nine hills, and in its channel were large quantities of drift trees. Seven of its tributaries also are said to have been "covered up with earth." A high tract of forest land, between the two great rivers before mentioned, is described as having been changed into an open country, destitute of trees, the surface being spread over with a fine red clay. This part of the account may, perhaps, merely refer to the sliding down of woody tracts into the valleys, as happened to so many extensive vineyards and olive grounds in Calabria, in 1783. The close packing of large trees in the Batavian river is represented as very remarkable, and it attests in a striking manner the destruction of soil bordering the

* Hooke's Posthumous Works, p. 437. 1705.

valleys which had been caused by floods and land-slips.*

Quito, 1698.—In Quito, on the 19th of July, 1698, during an earthquake, a great part of the crater and summit of the volcano Carguairazo fell in, and a stream of water and mud issued from the broken sides of the hill.†

Sicily, 1693.—Shocks of earthquakes spread over all Sicily in 1693, and on the 11th of January the city of Catania and forty-nine other places were levelled to the ground, and about one hundred thousand people killed. The bottom of the sea, says Vicentino Bonajutus, sank down considerably, both in ports, inclosed bays, and open parts of the coast, and water bubbled up along the shores. Numerous long fissures of various breadths were caused, which threw out sulphureous water; and one of them, in the plain of Catania (the delta of the Simeto), at the distance of four miles from the sea, sent forth water as salt as the sea. The stone buildings of a street in the city of Noto, for the length of half a mile, sank into the ground, and remained hanging on one side. In another street, an opening large enough to swallow a man and horse appeared.‡

Moluccas, 1693.—The small isle of Sorea, which consists of one great volcano, was in eruption in the year 1693. Different parts of the cone fell, one after the other, into a deep crater, until almost half the space of the island was converted into a fiery lake. Most of the inhabitants fled to Banda; but great pieces of the mountain continued to fall down, so that the lake of lava became wider; and finally the whole population was compelled to emigrate. It is stated that

* Phil. Trans. 1700. † Humboldt, Atl. Pit. p. 106.

‡ Phil. Trans. 1693-4.

in proportion as the burning lake increased in size, the earthquakes were less vehement.*

Jamaica, 1692. — In the year 1692, the island of Jamaica was visited by a violent earthquake ; the ground swelled and heaved like a rolling sea, and was traversed by numerous cracks, two or three hundred of which were often seen at a time, opening and then closing rapidly again. Many people were swallowed up in these rents ; some the earth caught by the middle, and squeezed to death ; the heads of others only appeared above ground ; and some were first engulfed, and then cast up again with great quantities of water. Such was the devastation, that even at Port Royal, then the capital, where more houses are said to have been left standing than in the whole island beside, three quarters of the buildings, together with the ground they stood on, sank down with their inhabitants entirely under water.

Subsidence in the harbour. — The large store-houses on the harbour side subsided, so as to be twenty-four, thirty-six, and forty-eight feet under water ; yet many of them appear to have remained standing, for it is stated that, after the earthquake, the mast-heads of several ships wrecked in the harbour, together with the chimney-tops of houses, were just seen projecting above the waves. A tract of land round the town, about a thousand acres in extent, sank down in less than one minute, during the first shock, and the sea immediately rolled in. The Swan frigate, which was repairing in the wharf, was driven over the tops of many buildings, and then thrown upon one of the roofs, through which it broke. The breadth of one of the streets is said to have been doubled by the earthquake.

* Phil. Trans. 1693.

According to Mr. De la Beche, the part of Port Royal described as having sunk was built upon newly formed land, consisting of sand, in which piles had been driven; and the *settlement* of this loose sand, charged with the weight of heavy houses, may, he suggests, have given rise to the subsidences alluded to.*

There have undoubtedly been instances in Calabria and elsewhere of slides of land on which the houses have still remained standing; and it is possible that such may have been the case at Port Royal. The fact at least of submergence is unquestionable, for I have been informed by Admiral Sir Charles Hamilton that he frequently saw the submerged houses of Port Royal in the year 1780, in that part of the harbour which lies between the town and the usual anchorage of men-of-war. Bryan Edwards also says, in his History of the West Indies, that in 1793 the *ruins* were visible in clear weather from the boats which sailed over them.† Lastly, Lieutenant B. Jeffery, R. N., tells me that, being engaged in a survey between the years 1824 and 1835, he repeatedly visited the site in question, where the depth of the water is from four to six fathoms, and, whenever there was but little wind, perceived distinct traces of houses. He saw these more clearly when he used the instrument called the “diver’s eye,” which is let down below the ripple of the wave.‡

At several thousand places in Jamaica the earth is related to have opened. On the north of the island, several plantations, with their inhabitants, were swallowed up, and a lake appeared in their place, covering above a thousand acres, which afterwards dried up,

* Manual of Geol. p. 133. second edition.

† Vol. i. p. 235. 8vo. ed. 3 vols. 1801.

‡ Letter to the Author, May, 1838.

leaving nothing but sand and gravel, without the least sign that there had ever been a house or a tree there. Several tenements at Yallows were buried under land-slips; and one plantation was removed half a mile from its place, the crops continuing to grow upon it uninjured. Between Spanish Town and Sixteen-mile Walk, the high and perpendicular cliffs bounding the river fell in, stopped the passage of the river, and flooded the latter place for nine days, so that the people "concluded it had been sunk as Port Royal was." But the flood at length subsided, for the river had found some new passage at a great distance.

Mountains shattered. — The Blue and other of the highest mountains are declared to have been strangely torn and rent. They appeared shattered and half-naked, no longer affording a fine green prospect, as before, but stripped of their woods and natural verdure. The rivers on these mountains first ceased to flow for about twenty-four hours, and then brought down into the sea, at Port Royal and other places, several hundred thousand tons of timber, which looked like floating islands on the ocean. The trees were in general barked, most of their branches having been torn off in the descent. It is particularly remarked in this, as in the narratives of so many earthquakes, that fish were taken in great numbers on the coast during the shocks. The correspondents of Sir Hans Sloane, who collected with care the accounts of eye-witnesses of the catastrophe, refer constantly to *subsidences*, and some supposed the whole of Jamaica to have sunk down.*

Reflections on the amount of change in the last one hundred and forty years. — I have now only enumerated the earthquakes of the last 150 years, respecting

* Phil. Trans. 1694.

which facts illustrative of geological inquiries are on record. Even if my limits permitted, it would be a tedious and unprofitable task to examine all the obscure and ambiguous narratives of similar events of earlier epochs ; although, if the places were now examined by geologists well practised in the art of interpreting the monuments of physical changes, many events which have happened within the historical era might still be determined with precision. It must not be imagined that, in the above sketch of the occurrences of a short period, I have given an account of all, or even the greater part, of the mutations which the earth has undergone by the agency of subterranean movements. Thus, for example, the earthquake of Aleppo, in the present century, and of Syria, in the middle of the eighteenth, would doubtless have afforded numerous phenomena, of great geological importance, had those catastrophes been described by scientific observers. The shocks in Syria, in 1759, were protracted for three months, throughout a space of ten thousand square leagues ; an area compared to which that of the Calabrian earthquake in 1783 was insignificant. Accon, Saphat, Balbeck, Damascus, Sidon, Tripoli, and many other places, were almost entirely levelled to the ground. Many thousands of the inhabitants perished in each ; and, in the valley of Balbeck alone, twenty thousand men are said to have been victims to the convulsion. In the absence of scientific accounts, it would be as irrelevant to our present purpose to enter into a detailed account of such calamities, as to follow the track of an invading army, to enumerate the cities burnt or rased to the ground, and reckon the number of individuals who perished by famine or the sword.

Deficiency of historical records. — If such, then, be the amount of ascertained changes in the last 150 years, notwithstanding the extreme deficiency of our records during that brief period, how important must we presume the physical revolutions to have been in the course of thirty or forty centuries, during which some countries habitually convulsed by earthquakes have been peopled by civilized nations ! Towns engulfed during one earthquake may, by repeated shocks, have sunk to great depths beneath the surface, while the ruins remain as imperishable as the hardest rocks in which they are enclosed. Buildings and cities, submerged, for a time, beneath seas or lakes, and covered with sedimentary deposits, must, in some places, have been re-elevated to considerable heights above the level of the ocean. The signs of these events have, probably, been rendered visible by subsequent mutations, as by the encroachments of the sea upon the coast, by deep excavations made by torrents and rivers, by the opening of new ravines, and chasms, and other effects of natural agents, so active in districts agitated by subterranean movements.

If it be asked why, if such wonderful monuments exist, so few have hitherto been brought to light, we reply — because they have not been searched for. In order to rescue from oblivion the memorials of former occurrences, the inquirer must know what he may reasonably expect to discover ; and under what peculiar local circumstances. He must be acquainted with the action and effect of physical causes, in order to recognize, explain, and describe correctly the phenomena when they present themselves.

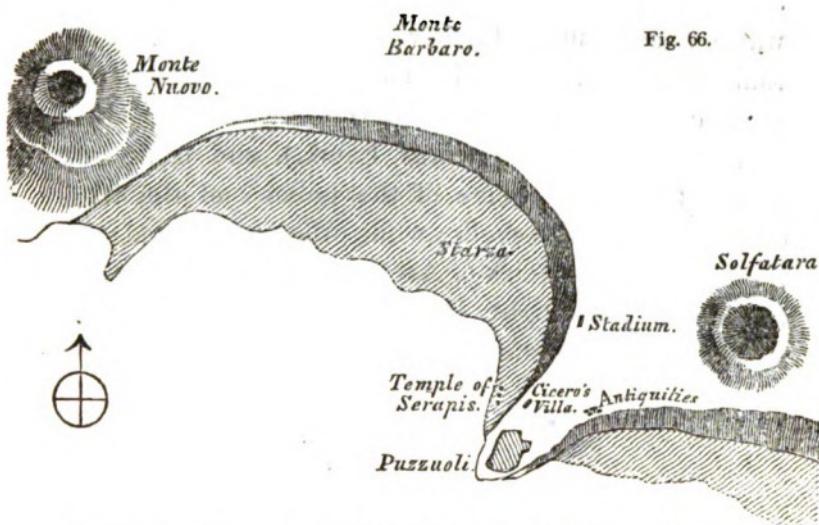
The best known of the great volcanic regions, of which the boundaries were sketched in the tenth chap-

ter, is that which includes Southern Europe, Northern Africa and Central Asia; yet nearly the whole, even of this region, must be laid down, in a geological map, as “*Terra Incognita*.” Even Calabria may be regarded as unexplored, as also Spain, Portugal, the Barbary States, the Ionian Isles, Asia Minor, Cyprus, Syria, and the countries between the Caspian and Black seas. We are, in truth, beginning to obtain some insight into one small spot of that great zone of volcanic disturbance, the district around Naples; a tract by no means remarkable for the violence of the earthquakes which have convulsed it.

If, in this part of Campania, we are enabled to establish, that considerable changes in the relative level of land and sea have taken place since the Christian era, it is all that we could have expected; and it is to recent antiquarian and geological research, not to history, that we are principally indebted for the information. I shall now proceed to lay before the reader some of the results of modern investigations in the Bay of Baiæ and the adjoining coast.

PROOFS OF ELEVATION AND SUBSIDENCE IN THE BAY OF BAIE.

Temple of Jupiter Serapis.—This celebrated monument of antiquity affords, in itself alone, unequivocal evidence that the relative level of land and sea has changed twice at Puzzuoli since the Christian era; and each movement, both of elevation and subsidence, has exceeded twenty feet. Before examining these proofs, I may observe, that a geological examination of the coast of the Bay of Baiæ, both on the north and south of Puzzuoli, establishes, in the most satis-



Ground plan of the coast of the Bay of Baiae, in the environs of Puzzuoli.

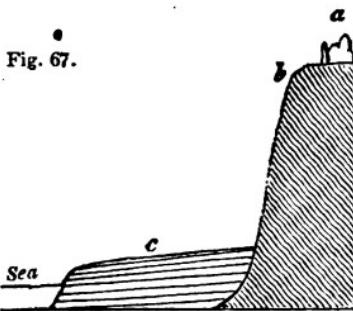
factory manner, an elevation, at no remote period, of more than twenty feet, and, at one point, of more than thirty feet; and the evidence of this change would have been complete, even if the temple had, to this day, remained undiscovered.

Coast south of Puzzuoli.—If we coast along the shore from Naples to Puzzuoli, we find, on approaching the latter place, that the lofty and precipitous cliffs of indurated tuff, resembling that of which Naples is built, retire slightly from the sea; and that a low level tract of fertile land, of a very different aspect, intervenes between the present sea-beach and what was evidently the ancient line of coast.

The inland cliff may be seen opposite the small island of Nisida, about two miles and a half south-east of Puzzuoli*, where, at the height of thirty-two feet above the level of the sea, Mr. Babbage observed an

* See Map, p. 149. Pl. VII. Fig. 2.

ancient mark, such as might have been worn by the waves ; and, upon further examination, discovered that, along that line, the face of the perpendicular rock, consisting of very hard tuff, was covered with barnacles (*Balanus sulcatus*, Lamk.), and drilled by boring testacea. Some of the hollows of the lithodomi contained the shells ; while others were filled with the valves of a species of *Arca*.* Nearer to Puzzuoli, the inland cliff is eighty feet high, and as perpendicular as if it was still undermined by the waves. At its



a, Antiquities on hill S. E. of Puzzuoli.
b, Ancient cliff now inland.
c, Terrace composed of recent submarine deposit.

base, a new deposit, constituting the fertile tract above alluded to, attains a height of about twenty feet above the sea ; and, since it is composed of regular sedimentary deposits, containing marine shells, its position proves that, subsequently to its formation, there has been a change of more than twenty feet in the relative level of land and sea.

The sea encroaches on these new incoherent strata ; and as the soil is valuable, a wall has been built for its

* Mr. Babbage examined this spot in company with Mr. Head, in June, 1828, and has shown me numerous specimens of the shells collected here, and in the Temple of Serapis.

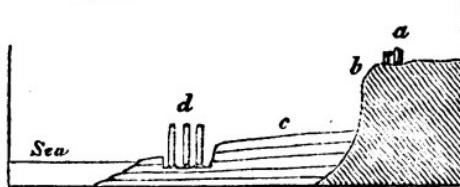
protection : but when I visited the spot in 1828, the waves had swept away part of this rampart, and exposed to view a regular series of strata of tuff, more or less argillaceous, alternating with beds of pumice and lapilli, and containing great abundance of marine shells, of species now common on this coast, and amongst them *Cardium rusticum*, *Ostrea edulis*, *Donax trunculus*, Lamk., and others. The strata vary from about a foot to a foot and a half in thickness, and one of them contains abundantly remains of works of art, tiles, squares of mosaic pavement of different colours, and small sculptured ornaments, perfectly uninjured. Intermixed with these I collected some teeth of the pig and ox. These fragments of building occur below as well as above strata containing marine shells. Puzzuoli itself stands chiefly on a promontory of the older tufaceous formation, which cuts off the new deposit, although I detected a small patch of the latter in a garden under the town.

From the town the ruins of a mole, called Caligula's Bridge, run out into the sea. This mole consists of a number of piers and arches ; and Mr. Babbage found, on the sixth pier, perforations of lithodomi four feet above the level of the sea ; and near the termination of the mole, on the last pier but one, marks of the same ten feet above the level of the sea, together with great numbers of balani and flustra.

Coast north of Puzzuoli.—If we then pass to the north of Puzzuoli, and examine the coast between that town and Monte Nuovo, we find a repetition of analogous phenomena. The sloping sides of Monte Barbaro slant down within a short distance of the coast, and terminate in an inland cliff of moderate elevation, to which the geologist perceives at once that the sea,

must, at some former period, have extended. Between this cliff and the sea is a low plain or terrace, called La Starza, corresponding to that before described on the south-east of the town; and as the sea encroaches rapidly, fresh sections of the strata may readily be obtained, of which the annexed is an example.

Fig. 68.



a, Remains of Cicero's villa, N. side of Puzzuoli.*

b, Ancient cliff now inland.

c, Terrace composed of recent submarine deposits.

d, Temple of Serapia.

Section on the shore north of the town of Puzzuoli: —

	Ft. In.
1. Vegetable soil	- - - - 1 0
2. Horizontal beds of pumice and scoriæ, with broken fragments of unrolled bricks, bones of animals, and marine shells	- - - 1 6
3. Beds of lapilli, containing abundance of marine shells, principally <i>Cardium rusticum</i> , <i>Donax trunculus</i> , Lam., <i>Ostrea edulis</i> , <i>Triton cutaceum</i> , Lam., and <i>Buccinum serratum</i> , Brocchi, the beds varying in thickness from one to eighteen inches	- - - 10 0
4. Argillaceous tuff, containing bricks and fragments of buildings not rounded by attrition	1 6

* The spot here indicated on the summit of the cliff is that from which Hamilton's view, plate 26., Campi Phlegræi, is taken, and on which, he observes, Cicero's villa, called the Academia, anciently stood.

The thickness of many of these beds varies greatly as we trace them along the shore, and sometimes the whole group rises to a greater height than at the point above described. The surface of the tract which they compose appears to slope gently upwards towards the base of the old cliffs.

Now, if these appearances presented themselves on the eastern or southern coast of England, a geologist would naturally endeavour to seek an explanation in some local depression of high-water mark, in consequence of a change in the set of the tides and currents: for towns have been built, like ancient Brighton, on sandy tracts intervening between the old cliff and the sea, and, in some cases, they have been finally swept away by the return of the ocean. On the other hand, the inland cliff at Lowestoffe, in Suffolk, remains, as was before stated, at some distance from the shore, and the low green tract called the Ness may be compared to the low flat called La Starza, near Puzzuoli.* But there are scarce any tides in the Mediterranean; and, to suppose that sea to have sunk generally from twenty to twenty-five feet since the shores of Campania were covered with sumptuous buildings, is an hypothesis obviously untenable. The observations, indeed, made during modern surveys on the moles and cothons (docks) constructed by the ancients in various ports of the Mediterranean, have proved that there has been no sensible variation of level in that sea during the last two thousand years.†

Thus we arrive, without the aid of the celebrated temple, at the conclusion, that the recent marine deposit at Puzzuoli was upraised in modern times above

* See Vol. II. p. 57.

† On the authority of Captain W. H. Smyth, R. N.

the level of the sea, and that not only this change of position, but the accumulation of the modern strata, was posterior to the destruction of many edifices, of which they contain the imbedded remains. If we now examine the evidence afforded by the temple itself, it appears, from the most authentic accounts, that the three pillars now standing erect continued, down to the middle of the last century, half buried in the new marine strata before described. The upper part of the columns, being concealed by bushes, had not attracted, until the year 1749, the notice of antiquaries; but, when the soil was removed in 1750, they were seen to form part of the remains of a splendid edifice, the pavement of which was still preserved, and upon it lay a number of columns of African breccia and of granite. The original plan of the building could be traced distinctly; it was of a quadrangular form, seventy feet in diameter, and the roof had been supported by forty-six noble columns, twenty-four of granite, and the rest of marble. The large court was surrounded by apartments, supposed to have been used as bathing-rooms; for a thermal spring, still used for medicinal purposes, issues now just behind the building, and the water, it is said, of this spring was conveyed by marble ducts into the chambers. .

Many antiquaries have entered into elaborate discussions as to the deity to which this edifice was consecrated; but Signor Carelli, who has written the last able treatise on the subject *, endeavours to show that all the religious edifices of Greece were of a form essentially different; that the building, therefore, could never have been a temple; that it corresponded to the public bathing-rooms at many of our watering-places;

* *Dissertazione sulla Sagra Architettura degli Antichi.*

and, lastly, that if it had been a temple, it could not have been dedicated to Serapis, the worship of the Egyptian god being strictly prohibited, at the time when this edifice was in use, by the senate of Rome.

Perforation of the columns by lithodomous shells. — It is not for the geologist to offer an opinion on these topics ; and I shall, therefore, designate this valuable relic of antiquity by its generally received name, and proceed to consider the memorials of physical changes inscribed on the three standing columns in most legible characters by the hand of Nature. (See Frontispiece, Vol. I.*) These pillars, which have been carved each out of a single block of marble, are forty-two feet in height. An horizontal fissure nearly intersects one of the columns ; the other two are entire. They are all slightly out of the perpendicular, inclining somewhat to the south-west, that is, towards the sea.† Their surface is smooth and uninjured to the height of about twelve feet above their pedestals. Above this is a zone, about nine feet in height, where the marble has been pierced by a species of marine perforating bivalve — *Lithodomus*, Cuv.‡ The holes of these animals are pear-shaped, the external opening being minute, and gradually increasing downwards. At the

* This view of the present state of the temple has been reduced from that of the Canonico Andrea de Jorio, *Ricerche sul Tempio di Serapide, in Puzzuoli.* Napoli, 1820.

† This appears from the measurement of Captain Basil Hall, R. N., *Proceedings of Geol. Soc.*, No. 38. p. 114. The fact of the three standing columns having been each formed out of a single stone was first pointed out to me by Mr. James Hall, and is important, as helping to explain why they were not shaken down.

‡ *Modiola lithophaga*, Lam. *Mytilus lithophagus*, Linn.

bottom of the cavities, many shells are still found, notwithstanding the great numbers that have been taken out by visitors; in many the valves of a species of arca, an animal which conceals itself in small hollows, occur. The perforations are so considerable in depth and size, that they manifest a long-continued abode of the lithodomi in the columns; for, as the inhabitant grows older and increases in size, it bores a large cavity, to correspond with the increasing magnitude of its shell. We must, consequently, infer a long-continued immersion of the pillars in sea-water, at a time when the lower part was covered up and protected by strata of tuff and the rubbish of buildings; the highest part, at the same time, projecting above the waters, and being consequently weathered, but not materially injured.

On the pavement of the temple lie some columns of marble, which are perforated in the same manner in certain parts; one, for example, to the length of eight feet, while, for the length of four feet, it is uninjured. Several of these broken columns are eaten into, not only on the exterior, but on the cross fracture, and, on some of them, other marine animals have fixed themselves.* All the granite pillars are untouched by lithodomi. The platform of the temple, which is not perfectly even, is at present (1828) about one foot below high-water mark (for there are small tides in the Bay of Naples); and the sea, which is only one hundred feet distant, soaks through the intervening soil. The upper part of the perforations, then, are at least twenty-three feet above high-water mark; and it is

* *Serpula contortuplicata*, Linn., and *Vermilia triquetra*, Lam. These species, as well as the *Lithodomus*, are now inhabitants of the neighbouring sea.

clear that the columns must have continued for a long time in an erect position, immersed in salt water. After remaining for many years submerged, they must have been upraised to the height of about twenty-three feet above the level of the sea.

Temples and Roman roads under water. — So far the information derived from the temple corroborates that before obtained from the new strata in the plain of La Starza, and proves nothing more. But, as the temple could not have been built originally at the bottom of the sea, it must have first sunk down below the waves, and afterwards have been elevated. Of such subsidences there are numerous independent proofs in the Bay of Baiæ. Not far from the shore, to the north-west of the Temple of Serapis, are the ruins of a temple of Neptune, and a temple of the Nymphs, now under water. The columns of the former edifice stand erect in five feet water, their upper portions just rising to the surface of the sea. The pedestals are doubtless buried in the mud; so that if this part of the bottom of the bay should hereafter be elevated, the exhumation of this temple might take place after the manner of that of Serapis. Both these buildings probably participated in the movement which raised the Starza; but, either they were deeper under water than the Temple of Serapis, or they were not raised up again to so great a height. There are also two Roman roads under water in the bay, one reaching from Puzzuoli towards the Lucrine Lake, which may still be seen, and the other near the Castle of Baiæ. The ancient mole, too, of Puzzuoli, before alluded to, has the water up to a considerable height of the arches; whereas Brieslak justly observes, it is next to certain that the piers must formerly have reached the

surface before the springing of the arches* ; so that, although the phenomena before described prove that this mole has been uplifted ten feet above the level at which it once stood, it is still evident that it has not yet been restored to its original position.

A modern writer also reminds us, that these effects are not so local as some would have us to believe ; for on the opposite side of the Bay of Naples, on the Sorrentine coast, which, as well as Puzzuoli, is subject to earthquakes, a road, with some fragments of Roman buildings, is covered to some depth by the sea. In the island of Capri, also, which is situated some way at sea, in the opening of the Bay of Naples, one of the palaces of Tiberius is now covered with water.† They who have attentively considered the effects of earthquakes, before enumerated, as having occurred during the last 150 years, will not feel astonished at these signs of alternate elevation and depression of the bed of the sea and the adjoining coast during the course of eighteen centuries ; but, on the contrary, they will be very much astonished if future researches fail to bring to light similar indications of change in almost all regions of volcanic disturbances.

That buildings should have been submerged, and afterwards upheaved, without being entirely reduced to a heap of ruins, will appear no anomaly, when we recollect that, in the year 1819, when the delta of the Indus sank down, the houses within the fort of Sindree

* Voy. dans la Campanie, tome ii. p. 162.

† Mr. Forbes, Physical Notices of the Bay of Naples. Ed. Journ. of Sci., No. II., new series, p. 280. October, 1829. When I visited Puzzuoli, and arrived at the above conclusions, I knew nothing of Mr. Forbes's observations, which I first saw on my return to England the year following.

subsided beneath the waves, without being overthrown. In like manner, in the year 1692, the buildings around the harbour of Port Royal, in Jamaica, descended suddenly to the depth of between thirty and fifty feet under the sea without falling. Even on small portions of land transported to a distance of a mile, down a declivity, tenements, like those near Mileto, in Calabria, were carried entire. At Valparaiso buildings were left standing in 1822, when their foundations, together with a long tract of the Chilian coast, were permanently upraised to the height of several feet. It is still more easy to conceive that an edifice may escape falling during the upheaval or subsidence of land, if the walls are supported on the exterior and interior with a deposit, like that which surrounded and filled to the height of ten or twelve feet the Temple of Serapis at Puzzuoli.

Periods when the Temple of Serapis sank and rose.—The next subject of inquiry is the era when these remarkable changes took place in the Bay of Baiae. It appears that, in the Atrium of the Temple of Serapis, inscriptions were found in which Septimius Severus and Marcus Aurelius record their labours in adorning it with precious marbles.* We may, therefore, conclude that it existed at least down to the third century of our era nearly in its original position; and it may have been built at the close of the second century. On the other hand, we have evidence that the marine deposit forming the flat land, called La Starza, was still covered by the sea in the year 1530, or just eight years anterior to the tremendous explosion of Monte Nuovo. Mr. Forbes has lately pointed out the

* Brieslak, *Voy. dans la Campanie*, tom. ii. p. 167.

distinct testimony of an old Italian writer, Loffredo, in confirmation of this important point.* Writing in 1580, Loffredo declares that, fifty years previously, the sea washed the base of the hills which rise from the flat land before alluded to; and at that time, he expressly tells us, a person *might have fished* from the site of those ruins which are now called the Stadium. (See p. 385. Fig. 66.) Hence it follows, that the subsidence of the ground happened at some period between the third century, when the temple was still standing, and the beginning of the sixteenth century, when its site was still submerged.

Now, in this interval, the only two events which are recorded in the imperfect annals of the dark ages are, the eruption of the Solfatara in 1198, and an earthquake in 1488, by which Puzzuoli was ruined. It is at least highly probable, that earthquakes, which preceded the eruption of the Solfatara, which is very near the temple (see p. 385. Fig. 66.) caused a subsidence, and the pumice and other matters ejected from that volcano might have fallen in heavy showers into the sea, and would thus immediately have covered up the lower part of the columns, and preserved them from the action of the sea and from lithodomous perforations. The waves might afterwards have thrown down many pillars, and formed strata of broken fragments of buildings, intermixed with volcanic ejections, and thus have caused those strata, containing works of art and shells, which extend for several miles along the coast. Mr. Babbage, after carefully examining several incrustations of carbonate of lime, such as the waters of the hot spring might have deposited, adhering to

* Ed. Journ. of Science, new series, No. II. p. 281.

the walls and columns of the temple at different heights, as also the distinct marks of ancient lines of water-level, visible below the zone of lithophagous perforations, has come to the conclusion, and I think, proved, that the subsidence of the building was not sudden, or at one period only, but gradual, and by successive movements.*

As to the re-elevation of the depressed tract, that may also have occurred at different periods, since earthquakes are not unfrequent in this country. Jorio cites two authentic documents in illustration of this point. The first, dated Oct. 1503, is a deed, written in Italian, by which Ferdinand and Isabella grant to the University of Puzzuoli a portion of land, "where the sea is drying up" (*che va seccando el mare*) ; the second, a document in Latin, dated May 23. 1511, or nearly eight years after, by which Ferdinand grants to the city a certain territory around Puzzuoli, where the ground *is dried up* from the sea (*desiccatum*).†

It is perfectly evident, however, from Loffredo's statement, that the principal elevation of the low tract called La Starza took place after the year 1530, and some time before the year 1580 ; and from this alone we might have suspected that the change happened in the year 1538, when Monte Nuovo was formed. But, fortunately, we are not left in the slightest doubt that such was the date of this remarkable event ; for in the descriptions before cited (p. 160.) of Falconi and Toledo of the convulsion of 1538, of which they were eye-witnesses, we find an express statement of the sea having abandoned a considerable tract of the shore, so that fish were taken by the inhabitants ; and among

* Proceedings of Geol. Soc., No. 36. March, 1834.

† Sul Tempio di Serap. chap. viii.

other things Falconi mentions that he saw two springs in the newly discovered ruins.

Encroachments of the sea in the Bay of Baiae.—The flat land, when first upraised, must have been more extensive than now, for the sea encroaches somewhat rapidly, both to the north and south-east of Puzzuoli. The coast has, of late years, given way more than a foot in a twelvemonth; and I was assured, by fishermen in the bay, that it has lost ground near Puzzuoli, to the extent of thirty feet, within their memory. By this gradual encroachment, the whole of the low land near the temple may perhaps, in the course of time be carried away, unless some new upheaval of the country shall take place, before the waves reach the ancient coast-line; but the removal of this narrow tract will by no means restore the country to its former state, for the old tufaceous hills, and the interstratified current of trachytic lava which has flowed from the Solfatara, must have participated in the movement of 1538; and these will remain upraised, even though the sea may regain its ancient limits.

It appears, however, from the recent memoir of Niccolini, published in 1838, that since the beginning of the 19th century, the Temple of Serapis has subsided more than two feet. That learned architect visited the ruins frequently, for the sake of making drawings, in the beginning of the year 1807, and was in the habit of remaining there throughout the day, yet never saw the pavement overflowed by the sea, except occasionally when the south wind blew violently. On his return, sixteen years after, to superintend some excavations ordered by the King of Naples, he found the pavement covered by sea-water twice every day at high tide, so that he was obliged to place there a

line of stones to stand upon. This induced him to make a series of observations with a hydrometer from Oct. 1822 to July 1838, by which means he ascertained that the ground has been and is sinking, at the average rate of about seven millimetres a year, or about one inch in four years; so that in 1838, fish were caught every day on that part of the pavement where, in 1807, there was never a drop of water in calm weather.*

By the excavations carried on in 1828, below the marble pavement of the temple, another costly pavement of mosaic was found, at the depth of about six feet below the other. The existence of these two pavements, at different levels, clearly implies some subsidence previously to all the changes already alluded to, which had rendered it necessary to construct a new floor at a higher level. From this fact, and from other analogous proofs, derived chiefly from the architectural investigations of Niccolini, we may infer that the soil forming the foundation of the Temple of Serapis has, in the course of the last nineteen centuries, undergone the following oscillations: — First, about eighty years before the Christian era, when the ancient mosaic pavement was constructed, it was about twelve feet *above* its actual level, or that at which it stood in 1838; secondly, towards the close of the first century after Christ, it was only six feet above its actual level; thirdly, by the end of the fourth century, it had nearly subsided to its present level; fourthly, in the middle ages, and before the eruption of Monte Nuovo, it was about nineteen feet *below* its present level; lastly, at the beginning of the present century, it was about two feet two inches *above* the level at which it now stands in 1838.

* *Tavola Metrica Chronologica, &c.* Napoli, 1838.

Signor Niccolini has, indeed, embraced the opinion that it is the sea which has risen and fallen, which Signor Capocci has successfully controverted, appealing to many appearances which attest the local character of the movements of the adjoining country, besides the historical fact, that in 1538, when the sea retired permanently 200 yards from the ancient shore at Puzzuoli, there was no simultaneous retreat of the waters from Naples, Castelamare, and Ischia.*

Mr. Babbage had arrived, as I before stated, by perfectly independent evidence, drawn from ancient calcareous deposits of the hot spring within the area of the temple, and from marine deposits associated with the same, and from lines of water-level at various heights, to the conclusion, that the subsidence of the temple was gradual, and that it continued until the pavement was at least nineteen feet below the level of the sea.†

Permanence of the ocean's level. — In concluding this subject, I may observe, that the interminable controversies to which the phenomena of the Bay of Baiae gave rise, have sprung from an extreme reluctance to admit that the land, rather than the sea, is subject alternately to rise and fall. Had it been assumed that the level of the ocean was invariable, on the ground that no fluctuations have as yet been clearly established, and that, on the other hand, the continents are inconstant in their level, as has been demonstrated by the most unequivocal proofs again and again, from the time of Strabo to our own times, the appearances of the Temple at Puzzuoli could never have been regarded as enigmatical. Even if contemporary accounts had not distinctly attested the upraising of the

* Nuove Ricerche sul Temp. di Serap.

† Proceedings Geol. Soc. vol. ii. p. 73.

coast, this explanation should have been proposed in the first instance as the most natural, instead of being now adopted unwillingly when all others have failed.

To the strong prejudices still existing in regard to the mobility of the land, we may attribute the rarity of such discoveries as have been recently brought to light in the Bay of Baiae and the Bay of Conception. A false theory, it is well known, may render us blind to facts which are opposed to our prepossessions, or may conceal from us their true import when we behold them. But it is time that the geologist should, in some degree, overcome those first and natural impressions which induced the poets of old to select the rock as the emblem of firmness—the sea as the image of inconstancy. Our modern poet, in a more philosophical spirit, saw in the sea “The image of eternity,” and has finely contrasted the fleeting existence of the successive empires which have flourished and fallen on the borders of the ocean with its own unchanged stability.

— Their decay

Has dried up realms to deserts : — not so thou,
Unchangeable, save to thy wild waves' play :
Time writes no wrinkle on thine azure brow ;
Such as creation's dawn beheld, thou rollest now.

CHILDE HAROLD, Canto iv.

CHAPTER XVIII.

ELEVATION AND SUBSIDENCE OF LAND WITHOUT EARTHQUAKES.

Changes in the relative level of land and sea in regions not volcanic — Opinion of Celsius that the waters of the Baltic Sea and Northern Ocean were sinking — Objections raised to his opinion — Proofs of the stability of the sea-level in the Baltic — Playfair's hypothesis that the land was rising in Sweden — Opinion of Von Buch — Marks cut on the rocks — Survey of these in 1820 — Facility of detecting slight alterations in level of sea on coast of Sweden — Shores of the ocean also rising — Area upheaved — Shelly deposits of Uddevalla — Of Stockholm, containing fossil shells characteristic of the Baltic — Subsidence in south of Sweden — Fishing-hut buried under marine strata — Sinking of land in Greenland — Bearing of these facts on geology.

WE have now considered the phenomena of volcanos and earthquakes according to the division of the subject before proposed (p. 120.), and have next to turn our attention to those slow and insensible changes in the relative level of land and sea which take place in countries remote from volcanos, and where no violent earthquakes have occurred within the period of human observation. Early in the last century the Swedish naturalist, Celsius, expressed his opinion that the waters, both of the Baltic and Northern Ocean, were gradually subsiding. From numerous observations he inferred, that the rate of depression was about forty

Swedish inches in a century.* In support of this position, he alleged that there were many rocks both on the shores of the Baltic and the ocean known to have been once sunken reefs, and dangerous to navigators, but which were in his time above water — that the waters of the Gulf of Bothnia had been gradually converted into land, several ancient ports having been changed into inland cities, small islands joined to the continent, and old fishing grounds deserted as being too shallow, or entirely dried up. Celsius also maintained, that the evidence of the change rested not only on modern observations, but on the authority of the ancient geographers, who had stated that Scandinavia was formerly an island. This island, he argued, must in the course of centuries, by the gradual retreat of the sea, have become connected with the continent; an event which he supposed to have happened after the time of Pliny, and before the ninth century of our era.

To this argument it was objected that the ancients were so ignorant of the geography of the most northern parts of Europe, that their authority was entitled to no weight; and that their representation of Scandinavia as an island, might with more propriety be adduced to prove the scantiness of their information, than to confirm so bold an hypothesis. It was also remarked, that if the land which connected Scandinavia with the main continent was laid dry between the time of Pliny and the ninth century, to the extent to which it is known to have risen above the sea at the latter period, the rate of depression could not have been uniform, as

* The Swedish measure scarcely differs from ours; the foot being divided into twelve inches, and being less than ours by three eighths of an inch only.

was pretended ; for it ought to have fallen much more rapidly between the ninth and eighteenth centuries.

Many of the proofs relied on by Celsius and his followers were immediately controverted by several philosophers, who saw clearly that a fall of the sea in any one region could not take place without a general sinking of the waters over the whole globe ; they denied that this was the fact, or that the depression was universal, even in the Baltic. In proof of the stability of the level of that sea, they appealed to the position of the island of Saltholm, not far from Copenhagen. This island is so low that, in autumn and winter it is permanently overflowed ; and it is only dry in summer, when it serves for pasturing cattle. It appears, from documents of the year 1280, that Saltholm was then also in the same state, and exactly on a level with the mean height of the sea, instead of having been about twenty feet under water, as it ought to have been, according to the computation of Celsius. Several towns, also, on the shores of the Baltic, as Lubeck, Wismar, Rostock, Stralsund, and others, after six and even eight hundred years, are as little elevated above the sea as at the era of their foundation, being now close to the water's edge. The lowest part of Dantzic was no higher than the mean level of the sea in the year 1000 ; and after eight centuries its relative position remains exactly the same.*

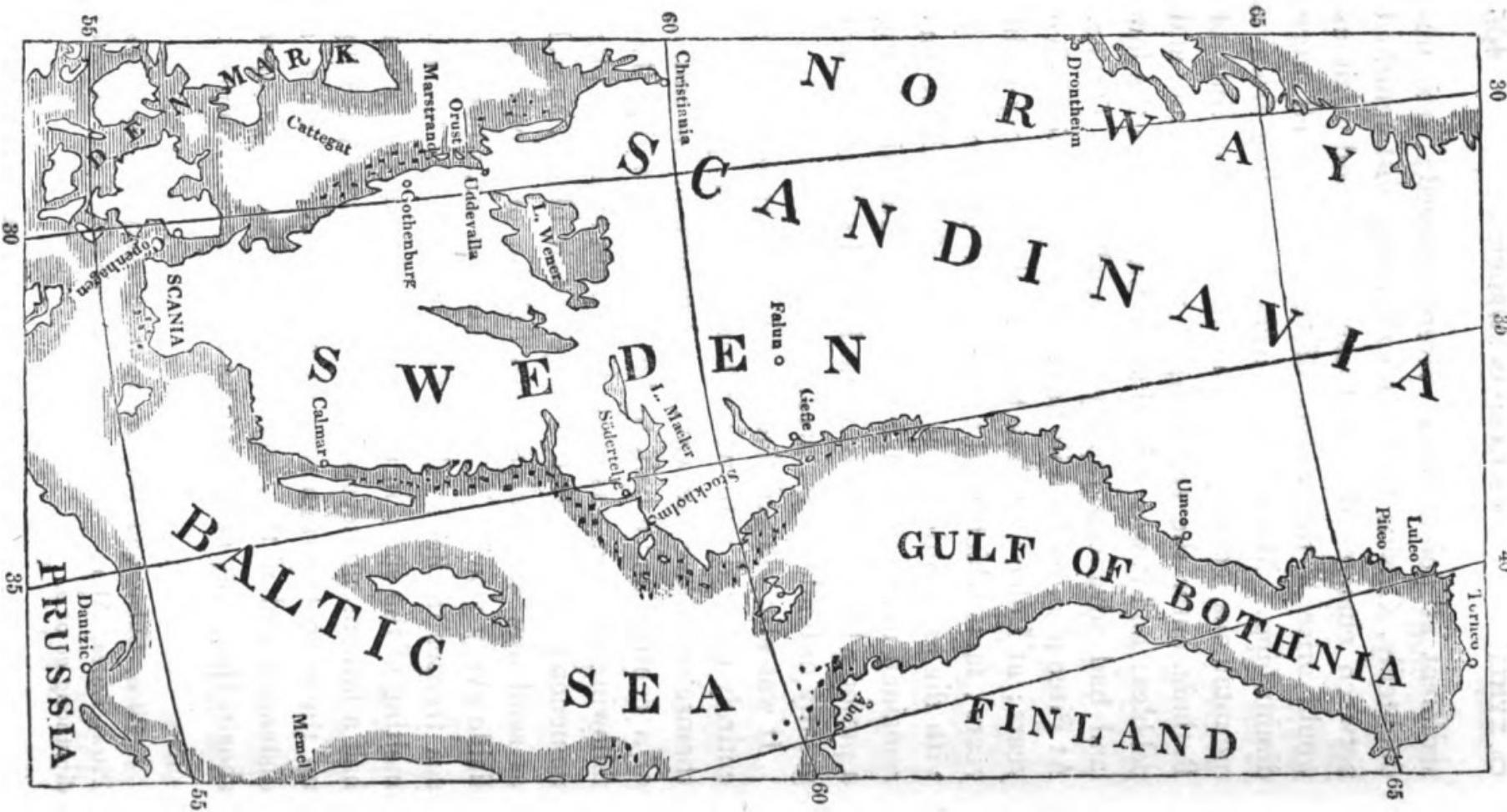
Several of the examples of the gain of land and shallowing of the sea pointed out by Celsius, and afterwards by Linnæus, who embraced the same opinions, were ascribed by others to the deposition of

* For a full account of the Celsian controversy, we may refer our readers to Von Hoff, *Geschichte, &c.* vol. i. p. 439.

sediment at points where rivers entered ; and, undoubtedly, Celsius had not sufficiently distinguished between changes due to these causes and such as would arise if the waters of the ocean itself were diminishing. Many large rivers descending from a mountainous country, at the head of the Gulf of Bothnia, enter the sea charged with sand, mud, and pebbles ; and it was said that in these places the low land had advanced rapidly, especially near Torneo. At Piteo also, half a mile had been gained in forty-five years ; at Luleo*, no less than a mile in twenty-eight years ; facts which might all be admitted consistently with the assumption that the level of the Baltic has remained unchanged, like that of the Adriatic, during a period when the plains of the Po and the Adige have greatly extended their area.

It was also alleged that certain insular rocks, once entirely covered with water, had at length protruded themselves above the waves, and grown, in the course of a century and a half, to be eight feet high. The following attempt was made to explain away this phenomenon :—In the Baltic, large erratic blocks, as well as sand and smaller stones which lie on shoals, are liable every year to be frozen into the ice, where the sea freezes to the depth of five or six feet. On the melting of the snow in spring, when the sea rises about half a fathom, numerous ice-islands float away, bearing up these rocky fragments so as to convey them to a distance ; and if they are driven by the waves upon shoals, they may convert them into islands by deposit-

* Piteo, Luleo, and Obo are spelt, in many English maps, Pitea, Lulea, Abo ; the *a* is not sounded in the Swedish diphthong *ao* or *å*.



E.P. 68.

ing the blocks; if stranded upon low islands, they may considerably augment their height.

Browallius, also, and some other Swedish naturalists, affirmed that some islands were lower than formerly; and that, by reference to this kind of evidence, there was equally good reason for contending that the level of the Baltic was gradually rising. They also added another curious proof of the permanency of the water-level, at some points at least, for many centuries. On the Finland coast were some large pines, growing close to the water's edge; these were cut down, and, by counting the concentric rings of annual growth, as seen in a transverse section of the trunk, it was demonstrated that they had stood there for four hundred years. Now, according to the Celsian hypothesis, the sea had sunk about fifteen feet during that period, in which case the germination and early growth of these pines must have been, for many seasons, below the level of the water. In like manner it was asserted, that the lower walls of many ancient castles, such as those of Sonderburg and Åbo, reached then to the water's edge, and must, therefore, according to the theory of Celsius, have been originally constructed below the level of the sea.

In reply to this last argument, Colonel Hällstrom, a Swedish engineer, well acquainted with the Finland coast, assured me, that the base of the walls of the castle of Åbo is now ten feet above the water, so that there may have been a considerable rise of the land at that point since the building was erected.

Playfair, in his "Illustrations of the Huttonian Theory," in 1802, admitted the sufficiency of the proofs adduced by Celsius, but attributed the change of level to the movement of the land, rather than to a diminu-

tion of the waters. He observed, "that in order to depress or elevate the absolute level of the sea, by a given quantity, in any one place, we must depress or elevate it by the same quantity over the whole surface of the earth; whereas no such necessity exists with respect to the elevation or depression of the land."* The hypothesis of the rising of the land, he adds, "agrees well with the Huttonian theory, which holds, that our continents are subject to be acted upon by the expansive forces of the mineral regions; that by these forces they have been actually raised up, and are sustained by them in their present situation."†

In the year 1807, Von Buch, after returning from a tour in Scandinavia, announced his conviction, "that the whole country, from Frederickshall in Norway to Åbo in Finland, and perhaps as far as St. Petersburg, was slowly and insensibly rising." He also suggested "that Sweden may rise more than Norway, and the northern more than the southern part."‡ He was led to these conclusions principally by information obtained from the inhabitants, and pilots, and in part by the occurrence of marine shells of recent species, which he had found at several points on the coast of Norway above the level of the sea. He also mentions the marks set on the rocks. Von Buch, therefore, has the merit of being the first geologist who, after a personal examination of the evidence, declared in favour of the rise of land in Scandinavia.

The attention excited by this subject in the early part of the last century, induced many philosophers in Sweden to endeavour to determine, by accurate observations, whether the standard level of the Baltic

* Sect. 393.

† Sect. 398.

‡ Transl. of his Travels, p. 387.

was really subject to periodical variations ; and under their direction, lines or grooves, indicating the ordinary level of the water on a calm day, together with the date of the year, were chiselled out upon the rocks. In 1820-21, all the marks made before those years were examined by the officers of the pilotage establishment of Sweden ; and in their report to the Royal Academy of Stockholm they declared, that on comparing the level of the sea at the time of their observations with that indicated by the ancient marks, they found that the Baltic was lower relatively to the land in certain places, but the amount of change during equal periods of time had not been every where the same. During their survey, they cut new marks for the guidance of future observers, several of which I had an opportunity of examining fourteen years after (in the summer of 1834), and in that interval the land appeared to me to have risen at certain places north of Stockholm four or five inches. I also convinced myself, during my visit to Sweden, after conversing with many civil engineers, pilots, and fishermen, and after examining some of the ancient marks, that the evidence formerly adduced in favour of the change of level, both on the coasts of Sweden and Finland, was full and satisfactory.* The alteration of level evidently diminishes as we proceed from the northern parts of the Gulf of Bothnia towards the south, being very slight around Stockholm. Some writers have indeed represented the rate of depression of the waters at

* In former editions I expressed many doubts as to the validity of the proofs of a gradual rise of land in Sweden. A detailed statement of the observations which I made in 1834, and which led me to change my opinion, will be found in the *Philosophical Transactions* for 1835, part i.

Stockholm as very considerable, because certain houses in that city which are built on piles have sunk down within the memory of persons still living, so as to be out of the perpendicular; and this in consequence of the tops of the piles giving way, and decaying, owing to a fall of the waters which has exposed them to be alternately wet and dry. The houses alluded to are situated on the borders of Lake Maeler, a large lake, the outlet of which joins the Baltic in the middle of Stockholm. This lake is certainly lower than formerly; but the principal cause of the change is not the elevation of the land, but the removal of two old bridges built on piles, which formerly obstructed the discharge of the fresh-water into the sea. Another cause is the opening, in the year 1819, of a new canal at Södertelje, a place south of Stockholm, by means of which a new line of communication was formed between Lake Maeler and the Baltic.*

It will naturally be asked, whether the mean level of a sea like the Baltic can ever be determined so exactly as to permit us to appreciate a variation of level, amounting only to one or two feet. In reply, I may observe, that, except near the Cattegat, there are no tides in the Baltic; and it is only when particular winds have prevailed for several days in succession, or at certain seasons when there has been an unusually abundant influx of river water, or when these causes have combined, that this sea is made to rise two or three feet above its standard level. The fluctuations due to these causes are nearly the same from year to year; so that the pilots and fishermen believe, and

* See Professor Johnston's Paper, Ed. New Phil. Journ., No. 29., July 1833; and my remarks, Phil. Trans. 1835, p. 12.

apparently with reason, that they can mark a deviation, even of a few inches, from the ordinary or mean height of the waters.

There are, moreover, peculiarities in the configuration of the shores of Norway and Sweden, which facilitate, in a remarkable degree, the appreciation of slight changes in the relative level of land and water. It has often been said, that there are two coasts, an inner and an outer one; the inner being the shore of the mainland; the outer one, a fringe of countless rocky islands of all dimensions, called the *skär* (*shair*). Boats and small vessels make their coasting voyages within this *skär*; for here they may sail in smooth water, even when the sea without is strongly agitated. But the navigation is very intricate, and the pilot must possess a perfect acquaintance with the breadth and depth of every narrow channel, and the position of innumerable sunken rocks. If on such a coast the land rises one or two feet in the course of half a century, the minute topography of the *skär* is entirely altered. To a stranger, indeed, who revisits it after an interval of many years, its general aspect remains the same; but the inhabitant finds that he can no longer penetrate with his boat through channels where he formerly passed; and he can tell of countless other changes in the height and breadth of isolated rocks, now exposed, but once only seen through the clear water.

The rocks of gneiss, mica-schist, and quartz, are usually very hard on this coast, slow to decompose, and, when protected from the breakers, remaining for ages unaltered in their form. Hence it is easy to mark the stages of their progressive emergence by the aid of natural and artificial marks imprinted on them.

Besides the summits of *fixed* rocks, there are numerous erratic blocks of vast size strewed over the shoals and islands in the skär, which have been probably drifted by ice in the manner before suggested.* All these are observed to have increased in height and dimensions within the last half century. Some, which were formerly known as dangerous sunken rocks, are now only hidden when the water is highest. On their first appearance, they usually present a smooth, bare, rounded protuberance, a few feet or yards in diameter; and a single sea-gull often appropriates to itself this resting-place, resorting there to devour its prey. Similar points, in the mean time, have grown to long reefs, and are constantly whitened by a multitude of sea-fowl; while others have been changed from a reef, annually submerged, to a small islet, on which a few lichens, a fir-seedling, and a few blades of grass, attest that the shoal has at length been fairly changed into dry land. Thousands of wooded islands around show the greater alterations which time can work. In the course of centuries also, the spaces intervening between the existing islands may be laid dry, and become grassy plains encircled by heights well clothed with lofty firs. This last step of the process, by which long fiords and narrow channels, once separating wooded islands, are deserted by the sea, has been exemplified within the memory of living witnesses on several parts of the coast.

Had the apparent fall of the waters been observed in the Baltic only, we might have endeavoured to explain the phenomenon by local causes affecting that sea alone. For instance, the channel by which the

* See p. 405.; also Vol. I. Book II. Chap. III.

Baltic discharges its surplus waters into the Atlantic, might be supposed to have been gradually widened and deepened by the waves and currents, in which case a fall of the water, like that before alluded to in Lake Maeler, might have occurred. But the lowering of level would in that case have been uniform and universal, and the waters could not have sunk at Torneo, while they retained their former level at Copenhagen. Such an explanation is also untenable on other grounds; for it is a fact, as Celsius long ago affirmed, that the alteration of level extends to the western shores of Sweden, bordering the ocean. The signs of elevation observed between Uddevalla and Gothenburg are as well established as those on the shores of the Bothnian Gulf. Among the places where they may be studied, are the islands of Marstrand and Gulholmen, the last-mentioned locality being one of those particularly pointed out by Celsius.

The inhabitants there and elsewhere affirm, that the rate of the sinking of the sea (or elevation of land) varies in different and adjoining districts, being greatest at points where the coast is low. But in this they are deceived; for they measure the amount of rise by the area gained, which is most considerable where the land descends with a gentle slope into the sea. In the same manner, some advocates of the Celsian theory formerly appealed to the increase of lands near the mouths of rivers, not sufficiently adverting to the fact, that if the bed of the sea is rising, the change will always be most sensible where the bottom has been previously rendered shallow; whereas, at a distance from these points, where the scarped granitic cliffs plunge at once into deep water, a much greater amount.

of elevation is necessary to produce an equally conspicuous change.

As to the area in northern Europe which is subject to this slow upheaving movement, we have not as yet sufficient data for estimating it correctly. It seems probable, however, that it reaches from Gothenburg to Torneo, and from thence to the North Cape, the rate of elevation increasing always as we proceed farther northwards. The two extremities of this line are more than a thousand geographical miles distant from each other; and as both terminate in the ocean, we know not how much farther the motion may be prolonged under water. As to the breadth of the tract, its limits are equally uncertain, though it evidently extends across the widest parts of the Gulf of Bothnia, and may probably stretch far into the interior, both of Sweden and Finland. Now, if the elevation continue, a larger part of the Gulf of Bothnia will be turned into land, as also more of the ocean off the west coast of Sweden between Gothenburg and Uddevalla; and, on the other hand, if the change has been going on for thousands of years at the rate of several feet in a century, large tracts of what is now land must have been submarine at periods comparatively modern. It is natural therefore to inquire whether there are any signs of the recent sojourn of the sea on districts now inland? The answer is most satisfactory.—Near Uddevalla and the neighbouring coastland, we find upraised deposits of shells belonging to species such as now live in the ocean; while on the opposite or eastern side of Sweden, near Stockholm, Gefle, and other places bordering the Bothnian Gulf, there are analogous beds containing shells of species characteristic of the Baltic.

Von Buch announced, in 1807, that he had discovered in Norway and at Uddevalla in Sweden, beds of shells of existing species, at considerable heights above the sea. Since that time, other naturalists have confirmed his observation ; and, according to Ström, deposits occur at an elevation of more than 400 feet above the sea in the northern part of Norway. M. Alex. Brongniart, when he visited Uddevalla, ascertained that one of the principal masses of shells, that of Capellbacken, is raised more than 200 feet above the sea, resting on rocks of gneiss, all the species being identical with those now inhabiting the contiguous ocean. The same naturalist also stated that on examining with care the surface of the gneiss, immediately above the ancient shelly deposit, he found barnacles (*balani*) adhering to the rocks, showing that the sea had remained there for a long time. I was fortunate enough to be able to verify this observation by finding, in the summer of 1834, at Kured, about two miles north of Uddevalla, and at the height of more than 100 feet above the sea, a surface of gneiss newly laid open by the partial removal of a mass of shells used largely in the district for making lime and repairing the roads. So firmly did these barnacles adhere to the gneiss that I broke off portions of the rock with the shells attached. The face of the gneiss was also encrusted with small zoophytes (*Cellepora* ? Lam.), but had these or the barnacles been exposed in the atmosphere ever since the elevation of the rocks above the sea, they would probably have decomposed and been obliterated.

The town of Uddevalla stands at the head of a narrow creek overhung by steep and barren rocks of gneiss, of which all the adjacent country is composed, except in the low grounds and bottoms of valleys,

where strata of sand, clay, and marl frequently hide the fundamental rocks. To these newer and horizontal deposits the fossil shells above mentioned belong, and similar marine remains are found at various heights above the sea on the opposite island of Orust. The extreme distance from the sea to which such fossils extend is as yet unknown, but they have been already found at Trollhättan in digging the canal there, and still farther inland on the northern borders of Lake Wener fifty miles from the sea, at an elevation of 200 feet, near Lake Rogvarpen.

To pass to the Baltic : I observed near its shores at Södertelje, sixteen miles S.W. of Stockholm, strata of sand, clay, and marl, more than 100 feet high, and containing shells of species now inhabiting the Bothnian Gulf. These consist partly of marine and partly of freshwater species ; but they are few in number, the brackishness of the water appearing to be very unfavourable to the development of testacea. The most abundant species are the common cockle, and the common mussel and periwinkle of our shores (*Cardium edule*, *Mytilus edulis*, and *Littorina littorea*), together with a small tellina (*T. Baltica*), and a few minute univalves allied to *Paludina ulva*. These live in the same waters as a *Lymneus*, a *Neritina* (*N. fluviatilis*), and some other freshwater shells.

But the marine mollusks of the Baltic above mentioned, although very numerous in individuals, are dwarfish in size, scarcely ever attaining a third of the average dimensions which they acquire in the salter waters of the ocean. By this character alone a geologist would generally be able to recognize an assemblage of Baltic fossils as distinguished from those derived from a deposit in the ocean. The absence also

of oysters, barnacles, whelks, scallops, limpets (*ostrea*, *balanus*, *buccinum*, *pecten*, *patella*), and many other forms abounding alike in the sea near Uddevalla, and in the fossiliferous deposits of modern date on that coast, supplies an additional negative character of the greatest value, distinguishing assemblages of Baltic from those of oceanic shells. Now the strata containing Baltic shells are found in many localities near Stockholm, Upsala, and Gefle, and will probably be discovered every where around the borders of the Bothnian Gulf; for I have seen similar remains brought from Finland, in marl resembling that found near Stockholm. The utmost distance to which these deposits have yet been traced inland, is on the southern shores of Lake Maejer, at a place seventy miles from the sea.* Hence it appears from the distinct assemblage of fossil shells found on the eastern and western coasts of Sweden, that the Baltic has been for a long period separated as now from the ocean, although the intervening tract of land was once much narrower, even after both seas had become inhabited by all the existing species of testacea.

As no accurate observations on the rise of the Swedish coast refer to periods more remote than a century and a half from the present time, and as traditional information, and that derived from ancient buildings on the coast, do not enable the antiquary to trace back any monuments of change for more than five or six centuries, we cannot declare whether the rate of the upheaving force is uniform during very long periods. In those districts where the fossil shells are found at the height of more than 200 feet above the ocean, as at Uddevalla, Orust, and Lake Rogvarpen,

* Phil. Trans. 1835, part i.

the present rate of rise seems less than four feet in a century. Even at that rate it would have required five thousand years to lift up those deposits. But as the movement is now very different in different places, it may also have varied much in intensity at different eras.

We have, moreover, yet to learn not only whether the motion proceeds always at the same rate, but also whether it has been uniformly *in one direction*. The level of the land may oscillate; and for centuries there may be a depression, and afterwards a re-elevation, of the same district. Some phenomena in the neighbourhood of Stockholm, appear to me only explicable on the supposition of the alternate rising and sinking of the ground since the country was inhabited by man. In digging a canal, in 1819, at Södertelje, about sixteen miles to the south of Stockholm, to unite Lake Maeler with the Baltic, marine strata, containing fossil shells of Baltic species, were passed through. At a depth of about sixty feet, they came down upon what seems to have been a buried fishing-hut, constructed of wood, in a state of decomposition, which soon crumbled away on exposure to the air. The lowest part, however, which had stood on a level with the sea, was in a more perfect state of preservation. On the floor of this hut was a rude fire-place, consisting of a ring of stones, and within this were cinders and charred wood. On the outside lay boughs of the fir, cut as with an axe, with the leaves or needles still attached. It seems impossible to explain the position of this buried hut, without imagining, as in the case of the Temple of Serapis (see p. 384.), first, a subsidence to the depth of more than sixty feet, then a re-elevation. During the period of submergence, the hut must

have become covered over with gravel and shelly marl, under which not only the hut, but several vessels also were found, of a very antique form, and having their timbers fastened together by wooden pegs instead of nails.*

Whether any of the land in Norway is now rising must be determined by future investigations. Marine fossil shells, of recent species, have been collected from inland places near Drontheim; but Mr. Everest, in his "Travels through Norway," informs us that the small island of Munkholm, which is an insulated rock in the harbour of Drontheim, affords conclusive evidence of the land having in that region remained stationary for the last eight centuries. The area of this isle does not exceed that of a small village, and by an official survey, its highest point has been determined to be twenty-three feet above the mean high water mark, that is, the mean between neap and spring tides. Now, a monastery was founded there by Canute the Great, A. D. 1028, and thirty-three years before that time it was in use as a common place of execution. According to the assumed average rate of rise in Sweden (about forty inches in a century), we should be obliged to suppose that this island had been three feet eight inches below high-water mark when it was originally chosen as the site of the monastery.

It has been already stated, that in proceeding from the North Cape to Stockholm, the rate of upheaval diminishes from several feet to a few inches in a century. To the south of Stockholm the upward movement ceases, and at length in Scania, or the southernmost part of Sweden, it appears to give place to a movement in an opposite direction. In proof of this

* See the paper before referred to, Phil. Trans. 1835, part i.

fact, Professor Nilsson observes, in the first place, that there are no elevated beds of recent marine shells in Scania like those farther to the north. Secondly, Linnæus, with a view of ascertaining whether the waters of the Baltic were retiring from the Scanian shore, measured, in 1749, the distance between the sea and a large stone near Trelleborg. This same stone was, in 1836, a hundred feet nearer the water's edge than in Linnæus's time, or eighty-seven years before. Thirdly, there is also a submerged peat moss consisting of land and freshwater plants, beneath the sea at a point to which no peat could have been drifted down by any river. Fourthly, and what is still more conclusive, it is found that in seaport towns, all along the coast of Scania, there are streets below the high-water level of the Baltic, and in some cases below the level of the lowest tide. Thus, when the wind is high at Malmö, the water overflows one of the present streets, and some years ago some excavations showed an ancient street in the same place eight feet lower, and it was then seen that there had been an artificial raising of the ground, doubtless in consequence of that subsidence. There is also a street at Trelleborg, and another at Skanör, a few inches below high-water mark, and a street at Ystad is exactly on a level with the sea, at which it could not have originally built.

The inferences deduced from the foregoing facts are in perfect harmony with the proofs lately brought to light by two Danish investigators, Dr. Pingel and Captain Graah, of the sinking down of part of the west coast of Greenland, for a space of more than 600 miles from north to south. The observations of Captain Graah were made during a survey of Greenland in 1823-24; and afterwards in 1828-29; those by Dr.

Pingel were made in 1830-32. It appears from various signs and traditions, that the coast has been subsiding for the last four centuries from the firth called Igaliko, in lat. $60^{\circ} 43' N.$, to Disco Bay, extending to nearly the 69th degree of north latitude. Ancient buildings on low rocky islands and on the shore of the mainland have been gradually submerged, and experience has taught the aboriginal Greenlander never to build his hut near the water's edge. In one case, the Moravian settlers have been obliged more than once to move inland the poles upon which their large boats were set, and the old poles still remain beneath the water as silent witnesses of the change.*

The probable cause of the movements above alluded to, whether of elevation or depression, will be more appropriately discussed in the following chapters, when the origin of subterranean heat is considered. But I may remark here, that the rise of Scandinavia has naturally been regarded as a very singular and scarcely credible phenomenon, because no region on the globe has been more free within the times of authentic history from violent earthquakes. In common, indeed, with our own island, and with almost every spot on the globe, some movements have been, at different periods, experienced, both in Norway and Sweden. But some of these, as for example during the Lisbon earthquake in 1755, may have been mere vibrations of the earth's crust prolonged from a great distance. Others, however, have been sufficiently local to indicate a source of disturbance immediately under the country itself. Notwithstanding these shocks Scandinavia has, upon the whole, been as tranquil in modern times, and

* See Proceedings of Geol. Soc., No. 42. p. 208. I also conversed with Dr. Pingel on the subject at Copenhagen in 1834.

as free from subterranean convulsions, as any region of equal extent on the globe. There is also another circumstance which has made the change of level in Sweden appear anomalous, and has for a long time caused the proofs of the fact to be received with reluctance. Volcanic action, as we have seen, is usually intermittent: and the variations of level to which it has given rise have taken place by starts, not by a prolonged and insensible movement similar to that experienced in Sweden. Yet, as we enlarge our experience of modern changes, we discover instances in which the volcanic eruption, the earthquake, and the permanent rise or fall of land, whether slow or sudden, are all connected. The union of these various circumstances was exemplified in the case of the Temple of Serapis, described in the last chapter, and we might derive other illustrations from the events of the present century in South America.

Some writers, indeed, have imagined that there is geological evidence in Norway of the sudden upheaval of land to a considerable height at successive periods, since the era when the sea was inhabited by the living species of testacea. They point in proof to certain horizontal lines of inland cliffs and sea-beaches containing recent shells at various heights above the level of the sea.* But these appearances, when truly interpreted, simply prove that there have been long pauses in the process of upheaval or subsidence. They mark eras at which the level of the sea has remained stationary for ages, and during which new strata were deposited near the shore in some places, while in others the waves and currents had time to hollow out rocks,

* Keilhau, *Bulletin de la Soc. Géol. de France*, tom. vii. p. 18.

undermine cliffs, and throw up long ranges of shingle. They undoubtedly show that the movement has not been always uniform or continuous, but they do not establish the fact of any sudden alterations of level.

When we are once assured of the reality of the gradual rise of a large region, it enables us to account for many geological appearances otherwise very difficult of explanation. There are large continental tracts and high table lands where the strata are nearly horizontal, bearing no marks of having been thrown up by violent convulsions, nor by a series of movements, such as those which occur in the Andes, and cause the earth to be rent open, and raised or depressed from time to time, while large masses are engulfed in subterranean cavities. The result of a series of such earthquakes might be to produce in a great lapse of ages a country of shattered, inclined, and perhaps vertical strata. But a movement like that of Scandinavia would cause the bed of the sea, and all the strata recently formed in it, to be upheaved so gradually, that it would merely seem as if the ocean had formerly stood at a higher level, and had slowly and tranquilly sunk down into its present bed.

The fact also of a very gradual and insensible elevation of land may explain many geological monuments of denudation, on a grand scale. If, for example, instead of the hard granitic rocks of Norway and Sweden, a large part of the bed of the Atlantic, consisting chiefly of soft strata, should rise up, century after century, at the rate of about half an inch, or an inch, in a year, how easily might oceanic currents, such as those described in the seventh chapter, sweep away the thin film of matter thus brought up annually within the sphere of aqueous denudation ! The tract,

when it finally emerged, might present table lands and ridges of horizontal strata, with intervening valleys and vast plains, where originally, and during its period of submergence, the surface was level and nearly uniform.

These speculations relate to superficial changes ; but others must be continually in progress in the subterranean regions. The foundations of the country, thus gradually uplifted in Sweden, must be undergoing important modifications. Whether we ascribe these to the expansion of solid matter by continually increasing heat, or to the liquefaction of rock, or to the crystallization of a dense fluid, or the accumulation of pent-up gases, in whatever conjectures we indulge, we can never doubt for a moment, that at some unknown depth beneath Sweden and the Baltic, the structure of the globe is in our own times becoming changed from day to day, throughout a space probably more than a thousand miles in length, and several hundred in breadth.

CHAPTER XIX.

CAUSES OF EARTHQUAKES AND VOLCANOS.

Intimate connexion between the causes of volcanos and earthquakes — Supposed original state of fusion of the planet. — Universal fluidity not proved by spheroidal figure of the earth — Attempt to calculate the thickness of the solid crust of the earth by precessional motion. — Heat in mines increasing with the depth — Objections to the supposed intense heat of a central fluid — Whether chemical changes may produce volcanic heat. — Currents of electricity circulating in the earth's crust — Theory of an unoxidated metallic nucleus — The metallic oxides when heated may be deoxidated by hydrogen.

IT will hardly be questioned, after the description before given of the phenomena of earthquakes and volcanos, that both of these agents have, to a certain extent, a common origin ; and I may now, therefore, proceed to inquire into their probable causes. But first, it may be well to recapitulate some of those points of relation and analogy which lead naturally to the conclusion, that they spring from a common source.

The regions convulsed by violent earthquakes include within them the site of all the active volcanos. Earthquakes, sometimes local, sometimes extending over vast areas, often precede volcanic eruptions. The subterranean movement and the eruption return again and again, at irregular intervals of time, and with unequal degrees of force, to the same spots. The action

of either may continue for a few hours, or for several consecutive years. Paroxysmal convulsions are usually followed, in both cases, by long periods of tranquillity. Thermal and mineral springs are abundant in countries of earthquakes and active volcanos. Lastly, hot springs situated in districts considerably distant from volcanic vents have been observed to have their temperature suddenly raised, and the volume of their water augmented, by subterranean movements.

All these appearances are evidently more or less connected with the passage of heat from the interior of the earth to the surface; and where there are active volcanos, there must exist, at some unknown depth below, enormous masses of matter intensely heated, and, in many instances, in a constant state of fusion. We have first, then, to inquire, whence is this heat derived?

It has long been a favourite conjecture, that the whole of our planet was originally in a state of igneous fusion, and that the central parts still retain a great portion of their primitive heat. Some have imagined, with the late Sir W. Herschel, that the elementary matter of the earth may have been first in a gaseous state, resembling those nebulae which we behold in the heavens, and which are of dimensions so vast, that some of them would fill the orbits of the remotest planets of our system. It is conjectured that such aërisome matter (for in many cases the nebulous appearance cannot be referred to clusters of very distant stars), if concentrated, might form solid spheres; and others have imagined that the evolution of heat, attendant on condensation, might retain the materials of the new globes in a state of igneous fusion.

Without dwelling on such speculations, which can

only have a distant bearing on geology, we may consider how far the spheroidal form of the earth affords sufficient ground for presuming that its primitive condition was one of universal fluidity. The discussion of this question would be superfluous, were the doctrine of original fluidity less popular ; for it may well be asked, why the globe should be supposed to have had a pristine shape different from the present one ? — why the terrestrial materials, when first called into existence, or assembled together in one place, should not have been subject to rotation, so as to assume at once that form which alone could retain their several parts in a state of equilibrium ?

Let us, however, concede that the statical figure may be a modification of some other pre-existing form, and suppose the globe to have been at first a perfect and quiescent sphere, covered with an uniform ocean — what would happen when it was made to turn round on its axis with its present velocity ? This problem has been considered by Playfair in his Illustrations, and he has decided, that if the surface of the earth, as laid down in Hutton's theory, has been repeatedly changed by the transportation of the detritus of the land to the bottom of the sea, the figure of the planet must in that case, whatever it may have been originally, be brought at length to coincide with the spheroid of equilibrium.* Sir John Herschel also, in reference to the same hypothesis, observes, “a centrifugal force would in that case be generated, whose general tendency would be to urge the water at every point of the surface to *recede* from the *axis*. A rotation might indeed be conceived so swift as to flirt the whole

* Illust. of Hutt. Theory, § 435—443.

ocean from the surface, like water from a mop. But this would require a far greater velocity than what we now speak of. In the case supposed, the *weight* of the water would still keep it *on* the earth; and the tendency to recede from the axis *could* only be satisfied therefore by the water leaving the poles, and flowing towards the equator; there heaping itself up in a ridge, and being retained in opposition to its weight or natural tendency towards the centre by the pressure thus caused. This, however, could not take place without laying dry the polar regions, so that protuberant land would appear at the poles, and a zone of ocean be disposed around the equator. This would be the first or immediate effect. Let us now see what would afterwards happen if things were allowed to take their natural course.

"The sea is constantly beating on the land, grinding it down, and scattering its worn-off particles and fragments, in the state of sand and pebbles, over its bed. Geological facts afford abundant proof that the existing continents have all of them undergone this process, even more than once, and been entirely torn in fragments, or reduced to powder, and submerged and reconstructed. Land, in this view of the subject, loses its attribute of fixity. As a mass it might hold together in opposition to forces which the water freely obeys; but in its state of successive or simultaneous degradation, when disseminated through the water, in the state of sand or mud, it is subject to all the impulses of that fluid. In the lapse of time, then, the protuberant land would be destroyed, and spread over the bottom of the ocean, filling up the lower parts, and tending continually to re-model the surface of the solid nucleus, in correspondence with the *form of equi-*

librium. Thus after a sufficient lapse of time, in the case of an earth in rotation the polar protuberances would gradually be cut down and disappear, being transferred to the equator (as being *then* the *deepest sea*), till the earth would assume by degrees the form we observe it to have — that of a flattened or *oblate ellipsoid*.

“ We are far from meaning here to trace the process *by which* the earth really assumed its actual form; all we intend is to show that this is the form to which, under a condition of a rotation on its axis, it must *tend*, and which it would attain even if originally and (so to speak) perversely constituted otherwise.” *

In this passage, the author has contemplated the superficial effects of aqueous causes only; but neither he nor Playfair seem to have followed out the same inquiry with reference to another part of Hutton’s system; namely, that which assumes the successive fusion by heat of different parts of the solid earth. Yet the progress of geology has continually strengthened the evidence in favour of the doctrine that local variations of temperature have melted one part after another of the earth’s crust, and this influence has perhaps extended downwards to the very centre. If, therefore, before the globe had assumed its present form, it was made to revolve on its axis, all matter to which freedom of motion was given by fusion must before consolidating have been impelled towards the equatorial regions in obedience to the centrifugal force. Thus lava flowing out in superficial streams would have its motion retarded when its direction was towards the pole, accelerated when towards the equator, or if lakes and seas

* Herschel’s Astronomy, chap. iii.

of lava existed beneath the earth's crust in equatorial regions, as probably now beneath the Peruvian Andes, the imprisoned fluid would force outwards and permanently upheave the overlying rocks. The statical figure, therefore, of the terrestrial spheroid (of which the longest diameter exceeds the shortest by about twenty-five miles), may have been the result of gradual and even of existing causes, and not of a primitive, universal, and simultaneous fluidity.

Experiments made with the pendulum, and observations on the manner in which the earth attracts the moon, have shown that our planet is not an empty sphere, but, on the contrary, that its interior, whether solid or fluid, has a higher specific gravity than the exterior. It has also been inferred, that there is a regular increase in density from the surface towards the centre, and that the equatorial protuberance is continued inwards; that is to say, that layers of equal density are arranged elliptically, and symmetrically, from the exterior to the centre. These conclusions, however, have been deduced rather as a consequence of the hypothesis of primitive and simultaneous fluidity than proved by experiment. The inequalities in the moon's motion, by which some have endeavoured to confirm them, are so extremely slight, that the opinion can be regarded as little more than a probable conjecture.

The mean density of the earth has been computed by Laplace to be about $5\frac{1}{2}$, or more than five times that of water. Now the specific gravity of many of our rocks is from $2\frac{1}{2}$ to 3, and the greater part of the metals range between that density and 21. Hence some have imagined that the terrestrial nucleus may be metallic — that it may correspond, for example,

with the specific gravity of iron, which is about 7. But here a curious question arises in regard to the form which materials, whether fluid or solid, might assume, if subjected to the enormous pressure which must obtain at the earth's centre. Water, if it continued to decrease in volume according to the rate of compressibility deduced from experiment, would have its density doubled at the depth of ninety-three miles, and be as heavy as mercury at the depth of 362 miles. Dr. Young computed that, at the earth's centre, steel would be compressed into one fourth, and stone into one eighth of its bulk.* It is more than probable, however, that after a certain degree of condensation, the compressibility of bodies may be governed by laws altogether different from those which we can put to the test of experiment; but the limit is still undetermined, and the subject is involved in such obscurity, that we cannot wonder at the variety of notions which have been entertained respecting the nature and conditions of the central nucleus. Some have conceived it to be fluid, others solid; some have imagined it to have a cavernous structure, and have even endeavoured to confirm this opinion by appealing to observed irregularities in the vibrations of the pendulum in certain countries.

An attempt has recently been made by Mr. Hopkins to determine the least thickness which can be assigned to the solid crust of the globe, if we assume the whole to have been once perfectly fluid, and a certain portion of the exterior to have acquired solidity by gradual refrigeration. This result he has endeavoured to obtain by a new solution of the delicate problem of the

* Young's Lectures, and Mrs. Somerville's Connexion of the Physical Sciences, p. 90.

precessional motion of the pole of the earth. It is well known that while the earth revolves round the sun the direction of its axis remains very nearly the same, i. e. its different positions in space are all nearly parallel to each other. This parallelism, however, is not accurately preserved, so that the axis, instead of coming exactly into the position which it occupied a year before, becomes inclined to it at a very small angle, but always retaining very nearly the same inclination to the plane of the earth's orbit. This motion of the pole changes the position of the equinoxes by about fifty seconds annually, and always in the same direction. Thus the pole-star, after a certain time, will entirely lose its claim to that appellation, until in the course of somewhat more than 25,000 years the earth's axis shall again occupy its present angular position, and again point very nearly as now to the pole-star. This motion of the axis is called *precession*. It is caused by the attraction of the sun and moon on the protuberant parts at the earth's equator, and if these parts were solid to a great depth, the motion thus produced would differ considerably from that which would exist if they were perfectly fluid, and incrusted over with a thin shell only a few miles thick. Mr. Hopkins has, therefore, calculated the amount of precessional motion which would result if we assume the earth to be constituted as above stated; i. e. fluid internally, and enveloped by a solid shell; and he finds that the amount will not agree with the observed motion, unless the crust of the earth be of a certain thickness. In calculating the exact amount some ambiguity arises in consequence of our ignorance of the effect of pressure in promoting the solidification of matter at high temperatures. The hypothesis least favourable for a great

thickness is found to be that which assumes the pressure to produce no effect on the process of solidification. Even on this extreme assumption the thickness of the solid crust must be nearly *four hundred miles*, and if the solidifying influence of pressure be considerable, it will probably require a shell of 800 miles to enable us to explain the observed amount of precession.*

At the same time it should be remarked, that any still *greater* thickness would be quite consistent with the actual phenomena; and these calculations are not opposed to the supposition of the general solidity of the entire globe. Nor do they preclude us from imagining that great lakes or seas of melted matter may be distributed through a shell 400 or 800 miles thick, provided they be so inclosed as to move with it, whatever motion of rotation may be communicated by the disturbing forces of the sun and moon.

Central Heat.—The hypothesis of internal fluidity calls for the more attentive consideration, as it has been found that the heat in mines augments in proportion as we descend. Observations have been made, not only on the temperature of the air in mines, but on that of the rocks, and on the water issuing from them. The mean rate of increase, calculated from results obtained in six of the deepest coal mines in Durham and Northumberland, is 1° Fahr. for a descent of forty-four English feet.† A series of observations, made in several of the principal lead and silver mines in Saxony, gave 1° Fahr. for every sixty-five feet. In this case, the bulb of the thermometer was introduced into cavities purposely cut in the solid rock at depths varying from two hundred to above nine hundred feet.

* Phil. Trans. 1839.

† Ed. Journal of Sci. April, 1832.

But in other mines of the same country, it was necessary to descend thrice as far for each degree of temperature.*

A thermometer was fixed in the rock of the Dolcoath mine, in Cornwall, by Mr. Fox, at the great depth of 1380 feet, and frequently observed during eighteen months; the mean temperature was 68° Fahr., that of the surface being 50°, which gives 1° for every seventy-five feet.

Kupffer, after an extensive comparison of the results in different countries, makes the increase 1° F. for about every thirty-seven English feet.† M. Cordier announces, as the result of his experiments and observations on the temperature of the interior of the earth, that the heat increases rapidly with the depth; but the increase does not follow the same law over the whole earth, being twice or three times as much in one country as in another, and these differences are not in constant relation either with the latitudes or longitudes of places.‡ He is of opinion, however, that the increase would not be overstated at 1° Cent. for every twenty-five metres, or about 1° F. for every forty-five feet.§ The experimental well now boring at Grenelle near Paris gave about 1° F. for every sixty English feet when they had reached a depth of 1312 feet.

Some writers have endeavoured to refer these phenomena (which, however discordant as to the ratio of increasing heat, appear all to point one way) to the

* Cordier, *Mém. de l'Instit.* tom. vii.

† Pog. *Ann.* tom. xv. p. 159.

‡ See M. Cordier's *Memoir on the Temperature of the Interior of the Earth*, read to the Academy of Sciences, 4th June, 1827.—*Edin. New Phil. Journal*, No. viii. p. 273.

§ Cordier, *Mém. de l'Instit.* tom. vii.

condensation of air constantly descending from the surface into the mines. For the air under pressure would give out latent heat, on the same principle as it becomes colder when rarified in the higher regions of the atmosphere. But, besides that the quantity of heat is greater than could be supposed to flow from this source, the argument has been answered in a satisfactory manner by Mr. Fox, who has shown, that in the mines of Cornwall the ascending have generally a higher temperature than the descending aërial currents. The difference between them was found to vary from 9° to 17° F.: a proof, that instead of imparting heat, these currents actually carry off a large quantity from the mines.*

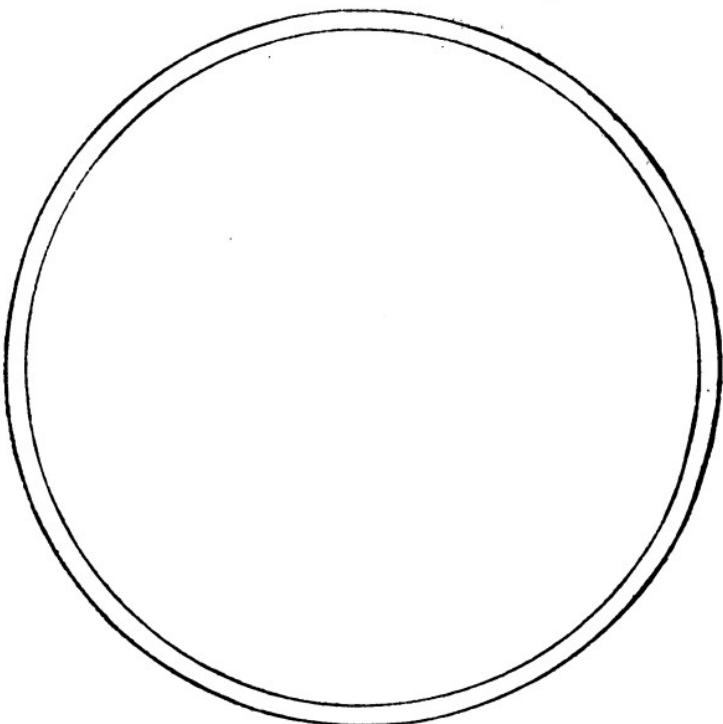
If we adopt M. Cordier's estimate of 1° F. for every 45 feet of depth as the mean result, and assume, with the advocates of central fluidity, that the increasing temperature is continued downwards, we should reach the ordinary boiling point of water at about two miles below the surface, and at the depth of about twenty-four miles should arrive at the melting point of iron, a heat sufficient to fuse almost every known substance. The temperature of melted iron was estimated at $21,000^{\circ}$ F., by Wedgwood; but his pyrometer gives, as is now demonstrated, very erroneous results. It has been ascertained by Professor Daniell, that the point of fusion is 2786° F.†

* Phil. Mag. and Ann. Feb. 1830.

† The heat was measured in Wedgwood's pyrometer by the contraction of pure clay, which is reduced in volume when heated, first by the loss of its water of combination, and afterwards on the application of more intense heat, by incipient vitrification. The expansion of platina is the test employed by Mr. Daniell, in his pyrometer, and this has been found to yield uniform and con-

According to Mr. Daniell's scale, we ought to encounter the internal melted matter before penetrating through a thickness represented by that of the outer circular line in the annexed diagram (Fig. 70.);

Fig. 70.



Section of the earth in which the breadth of the outer boundary line represents a thickness of 25 miles; the space between the circles including the breadth of the lines, 200 miles.

whereas, if the other or less correct scale be adopted, we should meet with it at some point between the two

sistent results, such as are in perfect harmony with conclusions drawn from various other independent sources. The instrument for which the author received the Rumford Medal from the Royal Society in 1833, is described in the Phil. Trans. 1830, part ii., and 1831, part ii.

circles ; the space between them, together with the lines themselves, representing a crust of two hundred miles in depth. In either case, we must be prepared to maintain, that a temperature many times greater than that sufficient to melt the most refractory substances known to us, is sustained at the centre of the globe ; while a comparatively thin crust, resting upon the fluid, remains unmelted ; or is even, according to M. Cordier, increasing in thickness, by the continual addition of new internal layers solidified during the process of refrigeration.

The mathematical calculations of Fourier, on the passage of heat through conducting bodies, have been since appealed to in support of these views ; for he has shown that it is compatible with theory that the present temperature of the surface might co-exist with an intense heat, at a certain depth below. But his reasoning seems to be confined to the conduction of heat through solid bodies ; and the conditions of the problem are wholly altered when we reason about a fluid nucleus, as we must do, if it be assumed that the heat augments from the surface to the interior, according to the rate observed in mines. For when the heat of the lower portion of a fluid is increased, a circulation begins throughout the mass, by the ascent of hotter, and the descent of colder currents. And this circulation, which is quite distinct from the mode in which heat is propagated through solid bodies, must evidently occur in the supposed central ocean, if the laws of fluids and of heat are the same there as upon the surface.

In Mr. Daniell's recent experiments for obtaining a measure of the heat of bodies, at their point of fusion, he invariably found that it was impossible to raise the

heat of a large crucible of melted iron, gold, or silver, a single degree beyond the melting point, so long as a bar of the respective metals was kept immersed in the fluid portions. So in regard to other substances, however great the quantities fused, their temperature could not be raised while any solid pieces immersed in them remained unmelted ; every accession of heat being instantly absorbed during their liquefaction. These results are, in fact, no more than the extension of a principle previously established, that so long as a fragment of ice remains in water, we cannot raise the temperature of the water above 32° F.

If, then, the heat of the earth's centre amount to 450,000° F., as M. Cordier deems highly probable, that is to say, about twenty times the heat of melted iron, even according to Wedgwood's scale, and upwards of 160 times according to the improved pyrometer, it is clear that the upper parts of the fluid mass could not long have a temperature only just sufficient to melt rocks. There must be a continual tendency towards a uniform heat ; and until this were accomplished, by the interchange of portions of fluid of different densities, the surface could not begin to consolidate. Nor, on the hypothesis of primitive fluidity, can we conceive any crust to have been formed until *the whole* planet had cooled down to about the temperature of incipient fusion.

It cannot be objected that hydrostatic pressure would prevent a tendency to equalization of temperature ; for, as far as observations have yet been made, it is found that the waters of deep lakes and seas are governed by the same laws as a shallow pool ; and no experiments indicate that solids resist fusion under high pressure. The arguments, indeed, now con-

troverted, always proceed on the admission that the internal nucleus is in a state of fusion.

It may be said that we may stand upon the hardened surface of a lava current while it is still in motion,—nay, may descend into the crater of Vesuvius after an eruption, and stand on the scoriæ while every crevice shows that the rock is red-hot two or three feet below us; and at a somewhat greater depth, all is, perhaps, in a state of fusion. May not, then, a much more intense heat be expected at the depth of several hundred yards, or miles? The answer is,—that, until a great quantity of heat has been given off, either by the emission of lava, or in a latent form by the evolution of steam and gas, the melted matter continues to boil in the crater of a volcano. But ebullition ceases when there is no longer a sufficient supply of heat from below, and then a crust of lava may form on the top, and showers of scoriæ may then descend upon the surface, and remain unmelted. If the internal heat be raised again, ebullition will recommence, and soon fuse the superficial crust. So in the case of the moving current, we may safely assume that no part of the liquid beneath the hardened surface is much above the temperature sufficient to retain it in a state of fluidity.

It may assist us in forming a clearer view of the doctrine now controverted, if we consider what would happen were a globe of homogeneous composition placed under circumstances analogous, in regard to the distribution of heat, to those above stated. If the whole planet, for example, were composed of water covered with a spheroidal crust of ice fifty miles thick, and with an interior ocean having a central heat about two hundred times that of the melting point of ice, or

6400° F.; and if, between the surface and the centre, there was every intermediate degree of temperature between that of melting ice and that of the central nucleus;—could such a state of things last for a moment? If it must be conceded, in this case, that the whole spheroid would be instantly in a state of violent ebullition, that the ice (instead of being strengthened annually by new internal layers) would soon melt, and form part of an atmosphere of steam—on what principle can it be maintained that analogous effects would not follow, in regard to the earth, under the conditions assumed in the theory of central heat?*

M. Cordier admits that there must be tides in the internal melted ocean; but their effect, he says, has become feeble, although originally, when the fluidity of the globe was perfect, “the rise and fall of these ancient land tides could not have been less than from thirteen to sixteen feet.” Now granting, for a moment, that these tides have become so feeble as to be incapable of causing the fissured shell of the earth to be first uplifted and then depressed every six hours, still may we not ask whether, during eruptions, the lava, which is supposed to communicate with a great central ocean,

* The above remarks are reprinted verbatim from my third edition, May 1834. A memoir was afterwards communicated by M. Poisson to the Academy of Sciences, January 1837, on the solid parts of the globe, containing an epitome of a work entitled “*Théorie Mathématique de la Chaleur*,” published in 1835. In this memoir he controverts the doctrine of the high temperature of a central fluid on similar grounds to those above stated. He imagines, that if the globe ever passed from a liquid to a solid state by radiation of heat, the central nucleus must have begun to cool and consolidate first.

would not rise and fall sensibly in a crater such as Stromboli, where there is always melted matter in a state of ebullition?

Whether chemical changes may produce volcanic heat.

— Having now explained the reasons which have induced me to question the hypothesis of central heat as the primary source of volcanic action, it remains to consider what has been termed the chemical theory of volcanos. It is well known that many, perhaps all, of the substances of which the earth is composed are continually undergoing chemical changes. To what depth these processes may be continued downwards must, in a great degree, be matter of conjecture; but there is no reason to suspect that, if we could descend to a great distance from the surface, we should find elementary substances differing essentially from those with which we are acquainted.

Playfair has, indeed, attempted to deduce, from an observation of Pallas, that we can, by the aid of geology, see, as it were, into the interior as far as thirty miles or more; for Pallas had described, in the peninsula of Tauris, a series of parallel strata as regular as the leaves of a book, inclined at an angle of 45° to the horizon, and exposed in a continuous section eighty-six English miles long. The height of the range of hills composed of these strata does not exceed twelve hundred feet; but if we measure the thickness of the stratified mass by a line perpendicular to its stratification, the height of the uppermost bed above the undermost must have been originally more than sixty miles; and even allowing, says Playfair, that the strata had shifted during their elevation, we may still suppose a thickness of thirty miles. But, if a deception to the extent of one half is allowed for, on the score of shift-

ing, it may well be asked why the same cause might not have produced a much greater amount of error? It is, moreover, an established doctrine with geologists that strata have, in many situations, accumulated originally on an inclined plane, as must now take place wherever sand, mud, and gravel are thrown into deep water by rivers and torrents. When the beds have been deposited in this manner on a slope they may easily be mistaken for horizontal strata which have been tilted by subsequent movements, and in that case a very exaggerated estimate would be formed of the vertical depth of the original deposit.

Nevertheless, since we discover in mountain chains strata thousands of feet thick, which must have been formed at the bottom of the sea, but are now raised to the height of three or four miles above it, we may fairly speculate on the probability of rocks, such as are now on the surface, existing at the depth of several leagues below.

We may next recall to mind that all the solid, fluid, and gaseous bodies which enter into the composition of the earth, consist of a very small number of elementary substances variously combined: the total number of elements at present known is less than sixty; and not half of these enter into the composition of the more abundant inorganic productions.

Some portions of the compounds above alluded to are daily resolved into their elements; and these, on being set free, are always passing into new combinations. These processes are by no means confined to the surface, and are almost always accompanied by the evolution of heat, which is intense in proportion to the rapidity of the combinations. At the same time, there is a development of electricity.

It is well known that mixtures of sulphur and iron, sunk in the ground, and exposed to moisture, give out sufficient heat to pass gradually into a state of combustion, and to set fire to any bodies that are near. The following experiment was first made by Lemery: Let a large quantity of clean iron filings be mixed with a still larger proportion of sulphur, and as much water as is necessary to make them into a firm paste. Let the mixture be then buried in the earth, and the soil pressed down firmly upon it. In a few hours it will grow warm, and swell so as to raise the ground; sulphureous vapours will make their way through the crevices, and sometimes flames appear. There is rarely an explosion; but, when this happens, the fire is vivid, and, if the quantity of materials is considerable, the heat and fire both continue for a long time.*

The spontaneous combustion of beds of bituminous shale, and of refuse coal thrown out of mines, is also generally due to the decomposition of pyrites; and it is the contact of water, not of air, which brings about the change. A smouldering heat results from the various new combinations, which immediately take place when the sulphur and other substances are set free. Similar effects are often produced in mines where no coaly matter is present, where substances capable of being decomposed by water are heaped together.

On what principle heat is generated, when two or more bodies having a strong affinity for each other unite suddenly, is wholly unexplained; but it is a singular fact that, while chemical combination causes heat, the disunion of elements does not produce the opposite effect, or a corresponding degree of cold. It

* Daubeny's Volcanos, p. 356.

may be said that decomposition is usually brought about by the combination of one or more of the elements with a new substance, and this concomitant agency might be supposed to neutralize or counter-balance any frigorific effects which might otherwise be sensible. But this explanation is, in many cases, wholly inapplicable; as, for example, when the voltaic pile is used for decomposition, or in the more striking instance of the well-known detonating powder, the iodide of nitrogen, which explodes with violence in the open air, the instant it is touched by a cold substance. The two elements into which this binary compound is resolved fly off in a gaseous form, and do not unite with any other body, the iodine rising in a purple vapour, while the nitrogen may be collected separately. Yet sudden as is the process by which their union is broken, we find that heat and light, instead of cold, are generated.

Electricity a source of volcanic heat.—It has already been stated, that chemical changes develop electricity; which, in its turn, becomes a powerful disturbing cause. As a chemical agent, says Davy, its silent and slow operation in the economy of nature is much more important than its grand and impressive operation in lightning and thunder. It may be considered, not only as directly producing an infinite variety of changes, but as influencing almost all which take place; it would seem, indeed, that chemical attraction itself is only a peculiar form of the exhibition of electrical attraction.*

Now that it has been demonstrated that magnetism and electricity are always associated, and are perhaps

* *Consolations in Travel*, p. 271.

only different conditions of the same power, the phenomena of terrestrial magnetism have become of no ordinary interest to the geologist. Soon after the first great discoveries of Oersted in electro-magnetism, Ampere suggested that all the phenomena of the magnetic needle might be explained by supposing currents of electricity to circulate constantly in the shell of the globe in directions parallel to the magnetic equator. This theory has acquired additional consistency the farther we have advanced in science; and according to the experiments of Mr. Fox, on the electro-magnetic properties of metalliferous veins, some trace of electric currents seems to have been detected in the interior of the earth.*

Some philosophers ascribe these currents to the chemical action going on in the superficial parts of the globe to which air and water have the readiest access; while others refer them, in part at least, to thermo-electricity excited by the solar rays on the surface of the earth during its rotation; successive parts of the land and sea being exposed to the influence of the sun, and then cooled again in the night. That this idea is not a mere speculation, is proved by the correspondence of the diurnal variations of the magnet with the apparent motion of the sun; and by the greater amount of variation in summer than in winter, and during the day than in the night. M. de la Rive, although conceding that such minor variations of the needle may be due to thermo-electricity, contends that the general phenomena of terrestrial magnetism must be attributed to currents far more intense; which, though liable to secular fluctuations, act with

* Phil. Trans. 1830, p. 399.

much greater constancy and regularity than the causes which produce the diurnal variations.* The remark seems just; yet it is difficult to assign limits to the accumulated influence even of a very feeble force constantly acting on the whole surface of the earth. This subject, however, must evidently remain obscure, until we become acquainted with the causes which give a determinate direction to the supposed electric currents. Already the experiments of Faraday on the rotation of magnets have led him to speculate on the manner in which the earth, when once it had become magnetic, might produce electric currents within itself, in consequence of its diurnal rotation.†

Before leaving the consideration of thermo-electricity, I may remark, that it may be generated by great inequalities of temperature, arising from a partial distribution of volcanic heat. Wherever, for example, masses of rock occur of great horizontal extent, and of considerable depth, which are at one point in a state of fusion (as beneath some active volcano); at another, red hot; and at a third, comparatively cold — strong thermo-electric action may be excited.

Some, perhaps, may object, that this is reasoning in a circle; first to introduce electricity as one of the primary causes of volcanic heat, and then to derive the same heat from thermo-electric currents. But there must, in truth, be much reciprocal action between the agents now under consideration; and it is very difficult to decide which should be regarded as the prime mover, or to see where the train of changes, once begun, would terminate.

* Biblioth. Univers., 1833, *Electricité*.

† Phil. Trans., 1832, p. 176.; also pp. 172, 173, &c.

In the ordinary operations of nature, it is in the atmosphere alone that we observe the action of electricity; and it is probable that a moment never passes without a flash of lightning striking some part of the earth. The electric fluid shatters rocks, and instantaneously melts substances which are commonly regarded as infusible. The air is supposed to derive a great part of this electricity directly from the earth *; and M. Necker seems to have succeeded in establishing that there is a connection between the direction of the curves of equal magnetic intensity and the *strike* of the principal mountain chains.† Some, also, attribute the electricity of the air to the evaporation of sea-water by the sun: for it can be shown, by experiment, that the conversion of salt water into vapour is accompanied by the excitement of electricity; and the process alluded to takes place on so vast a scale,—the measure of the quantity of evaporation being the constant flow of all the rivers of the earth exclusive of the rain which falls directly into the ocean,—that a feeble action of this kind may become very powerful by accumulation.

During volcanic eruptions, vivid lightnings are almost invariably seen in the clouds of vapour which ascend from the crater; and, as there are always one or more eruptions going on in some part of the globe, we are here presented with another perpetual source of derangement. How far subterranean electric currents may possess the decomposing power of the voltaic pile is a question for those alone who are farthest advanced in the career of discovery in a rapidly pro-

* Faraday, Phil. Trans., 1832, p. 177.

† Biblioth. Univers., tom. xliii. p. 166.

gressive science ; but such a power would at once supply us with a never-failing source of chemical action, from which volcanic heat might be derived.

Recapitulation. — In the next chapter I shall enter still further into the inquiry, how far the phenomena of volcanos and earthquakes accord with the hypothesis of a continued generation of heat by chemical action. But, first, it may be desirable to recapitulate, in a few words, the conclusions already obtained.

1st. The primary causes of the volcano and the earthquake are, to a great extent, the same, and must be connected with the passage of heat from the interior to the surface.

2dly. This heat has been referred, by many, to a supposed state of igneous fusion of the central parts of the planet when it was first created, of which a part still remains in the interior, but is always diminishing in intensity.

3dly. The spheroidal figure of the earth, adduced in support of this theory, does not of necessity imply an universal and simultaneous fluidity, in the beginning; for supposing the original figure of our planet had been strictly spherical — which, however, is a gratuitous assumption, resting on no established analogy — still the statical figure must have been assumed, if sufficient time be allowed, by the gradual operation of the centrifugal force, acting on the materials brought successively within its action by aqueous and igneous causes.

4thly. It appears, from experiment, that the heat in mines increases progressively with their depth ; and if the ratio of increase be continued uniformly from the surface to the interior, the whole globe, with the exception of a small external shell, must be fluid, and

the central parts must have a temperature many times higher than that of melted iron.

5thly. But the theory adopted by M. Cordier and others, which maintains the actual existence of such a state of things, seems wholly inconsistent with the laws which regulate the circulation of heat through fluid bodies. For, if the central heat were as intense as is represented, there must be a circulation of currents, tending to equalize the temperature of the resulting fluids, and the solid crust itself would be melted.

6thly. Instead of an original central heat, we may, perhaps, refer the heat of the interior to chemical changes constantly going on in the earth's crust; for the general effect of chemical combination is the evolution of heat and electricity, which, in their turn, become sources of new chemical changes.

7thly. The existence of currents of electricity in the shell of the earth has been deduced from the phenomena of terrestrial magnetism; from the connection between the diurnal variations of the magnet and the apparent motion of the sun; from observations on the electro-magnetic properties of metalliferous veins; and, lastly, from atmospheric electricity, which is continually passing between the air and the earth.

8thly. Subterranean electric currents may exert a slow decomposing power like that of the voltaic pile, and thus become a constant source of chemical action, and, consequently, of volcanic heat.

CHAPTER XX.

CAUSES OF EARTHQUAKES AND VOLCANOS — *continued.*

Review of the proofs of internal heat — Theory of an unoxidated metallic nucleus — Decomposition of water a source of volcanic heat — Geysers of Iceland — Causes of earthquakes — Wave-like motion — Expansive power of liquid gases — Connexion between the state of the atmosphere and earthquakes — Permanent upheaval and subsidence of land — Expansion of rocks by heat — The balance of dry land how preserved — Subsidence in excess — Conclusion.

WHEN we reflect that the largest mountains are but insignificant protuberances upon the surface of the earth, and that these mountains are nevertheless composed of different parts which have been formed in succession, we may well feel surprise that the central fluidity of the planet should have been called in to account for volcanic phenomena. To suppose the entire globe to be in a state of igneous fusion, with the exception of a solid shell, not more than from thirty to one hundred miles thick, and to imagine that the central heat of this fluid spheroid exceeds by more than two hundred times that of liquid lava, is to introduce a force altogether disproportionate to the effects which it is required to explain.

The ordinary repose of the surface implies, on the contrary, an inertness in the internal mass which is

truly wonderful. When we consider the combustible nature of the elements of the earth, so far as they are known to us,—the facility with which their compounds may be decomposed, and made to enter into new combinations,—the quantity of heat which they evolve during these processes; when we recollect the expansive power of steam, and that water itself is composed of two gases which, by their union, produce intense heat; when we call to mind the number of explosive and detonating compounds which have been already discovered, we may be allowed to share the astonishment of Pliny, that a single day should pass without a general conflagration:—“*Excedit profectò omnia miracula, ullum diem fuisse quo non cuncta conflagrarent.*”*

The signs of internal heat observable on the surface of the earth do not necessarily indicate the permanent existence of subterranean heated masses, whether fluid or solid, by any means so vast as our continents and seas; yet how insignificant would these appear if distributed through an external shell of the globe one or two hundred miles in depth! The principal facts in proof of the accumulation of heat below the surface may be summed up in a few words. Several volcanos are constantly in eruption, as Stromboli and Nicaragua; others are known to have been active for periods of 60, or even 150 years, as those of Sangay in Quito, Popocatepetl in Mexico, and the volcano of the Isle of Bourbon. Many craters emit hot vapours in the intervals between eruptions, and solfataras evolve incessantly the same gases as volcanos. Steam of high temperature has continued for more than twenty cen-

* *Hist. Mundi*, lib. ii. c. 107.

turies to issue from the “stufas,” as the Italians call them,—thermal springs abound not only in regions of earthquakes, but are found in almost all countries, however distant from active vents; and, lastly, the temperature in the mines of various parts of the world is found to increase in proportion as we descend.

It is probably to this unceasing discharge of subterranean heat that we owe the general tranquillity of the globe; and the occasional convulsions which occur may arise from the temporary stoppage of the channels by which heat is transmitted to the surface; for the passage of caloric from below upwards may be compared to the descent of water from the continents to the sea; and as a partial interruption of the drainage of a country causes a flood, so any obstruction to the discharge of volcanic heat may give rise to an earthquake or eruption.

The annexed diagram (fig. 71.) may convey some idea of the proportion which our continents and the ocean bear to the radius of the earth.* If all the land were about as high as the Himalaya mountains, and the ocean every where as deep as the Pacific, the whole of both might be contained within a space expressed by the thickness of the line *a b*; and masses of nearly equal volume might be placed in the space marked by the line *c d*, in the interior. Seas of lava, therefore, of the size of the Mediterranean, or even of the Atlantic, would be as nothing if distributed through such an outer shell of the globe as is represented by the shaded portion of the figure *a b c d*. If throughout that space we imagine electro-chemical

* Reduced, by permission, from a figure in plate 40. of Mr. De la Beche's Geological Sections and Views.

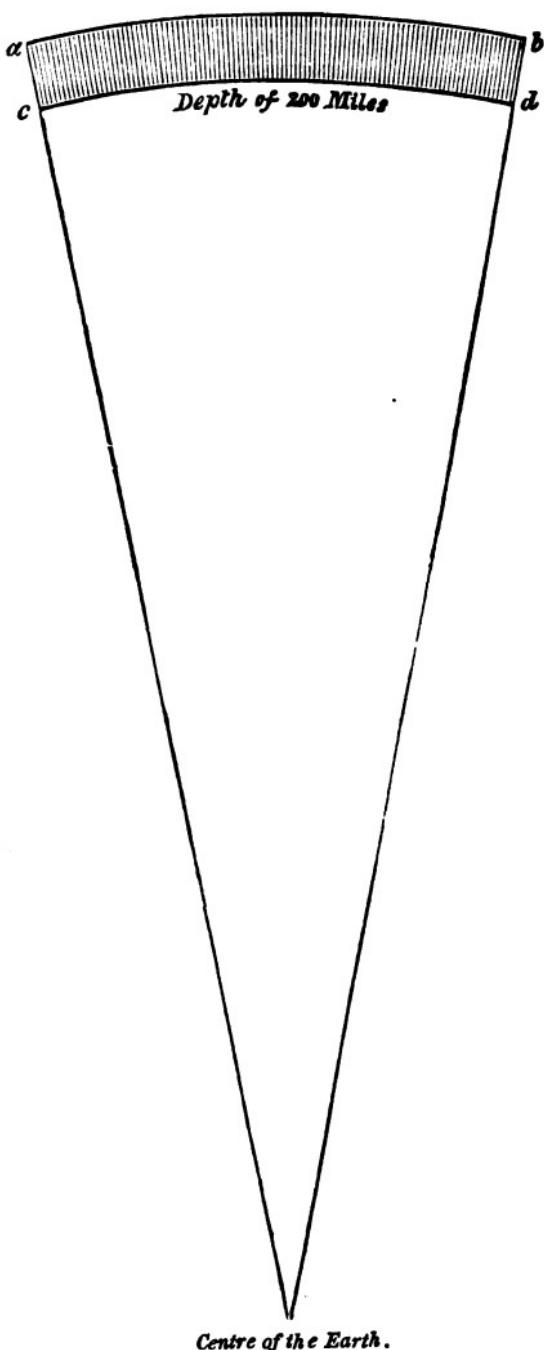


Fig. 71.

causes to be continually in operation, even of very feeble power, they might give rise to heat which, if accumulated at certain points, might melt or render red-hot entire mountains, or sustain the temperature of stufas and hot springs for ages.

Theory of an unoxidized metallic nucleus. — When Sir H. Davy first discovered the metallic bases of the earths and alkalies, he threw out the idea that those metals might abound in an unoxidized state in the subterranean regions to which water must occasionally penetrate. Whenever this happened, gaseous matter would be set free, the metals would combine with the oxygen of the water, and sufficient heat might be evolved to melt the surrounding rocks. This hypothesis was at first very favourably received both by the chemist and the geologist; for silica, alumina, lime, soda, and oxide of iron, — substances of which lavas are principally composed, — would all result from the contact of the inflammable metals alluded to with water. But whence this abundant store of unsaturated metals in the interior? It was assumed that, in the beginning of things, the nucleus of the earth was mainly composed of inflammable metals, and that oxidation went on with intense energy at first; till, at length, when a superficial crust of oxides had been formed, the chemical action became more and more languid.

If we indulge in this speculation, which, like all others respecting the primitive state of the earth's nucleus is arbitrary, we are naturally led to inquire whether any existing causes may have the power of deoxidating the earthy and alkaline compounds formed from time to time by the action of water upon the metallic bases. If so the previous state of the metallic

bases might be restored, a permanent chemical action sustained, and a continual circle of operation kept up. It has been suggested to me, by Mr. Daniell, that we have, in hydrogen, precisely such a deoxidizing agent as would be required. It is well known to chemists, that the metallization of oxides, the most difficult to reduce, may be effected by hydrogen brought into contact with them at a red heat; and it is more than probable that the production of potassium itself, in the common gun-barrel process, is due to the power of nascent hydrogen derived from the water which the hydrated oxide contains. According to the recent experiments, also, of Faraday, it would appear that every case of metallic reduction by voltaic agency, from saline solutions, in which water is present, is due to the secondary action of hydrogen upon the oxide; both of these being determined to the negative pole and then re-acting upon one another.

It has never been disputed that intense heat might be produced by the occasional contact of water with the metallic bases; and it is quite certain that, during the process of saturation, vast volumes of hydrogen must be evolved. The hydrogen, thus generated, might permeate the crust of the earth in different directions, and be stored up for ages in fissures and caverns, sometimes in a liquid form, under the necessary pressure. Whenever, at any subsequent period, in consequence of the changes effected by earthquakes in the shell of the earth, this gas happened to come in contact with metallic oxides at a high temperature, the reduction of these oxides would be the necessary result.

No theory seems at first more improbable, than that which represents water as affording an inexhaustible

supply of fuel to the volcanic fires; yet the hypothesis is far from visionary; and it is a fact that must never be overlooked, that while a great number of volcanos are entirely submarine, the remainder are for the most part in islands or maritime tracts. There are a few exceptions, but some of these, as Dr. Daubeny observes, are near inland salt lakes, as in Central Tartary; while others form part of a train of volcanos, the extremities of which are near the sea. Thus Jorullo, in Mexico, though itself not less than forty leagues from the nearest ocean, appears to be connected with the volcano of Tuxtla on the one hand, and that of Colima on the other; the first bordering on the Atlantic, the latter on the Pacific Ocean. This communication is rendered more probable by the parallelism that exists between these and several intermediate volcanic hills.*

Sir H. Davy supposes that, when the sea is distant, as in the case of some of the South American volcanos, they may still be supplied with water from subterranean lakes; since, according to Humboldt, large quantities of fish are often thrown out during eruptions.†

When treating of springs and overflowing wells, I have stated that porous rocks are percolated by fresh water to great depths, and that sea-water probably penetrates in the same manner through the rocks which form the bed of the ocean. But, besides this universal circulation in regions not far from the surface, it must be supposed that, wherever earthquakes prevail, much larger bodies of water will be forced by the pressure

* See Daubeny's remarks — "Volcanos," p. 368.

† Phil. Trans., 1828, p. 250.

of the ocean into fissures at greater depths, or swallowed up in chasms ; in the same manner as, on the land, towns, houses, cattle, and trees are sometimes engulfed. It will be remembered, that these chasms often close again after houses have fallen into them ; and for the same reason, when water has penetrated to a mass of melted lava, the steam into which it is converted may often rush out at a different aperture from that by which the water entered. The frequent explosions caused by the generation of steam in the neighbourhood of the sea or of deep lakes, may shatter the solid crust of the earth, and allow the free escape of gases and lava which, but for this cause, might never have reached the surface, and might only have given rise to earthquakes.

It seems generally admitted, that the gases exhaled from volcanos, together with steam, are such as would result from the decomposition of salt water, and the fumes which escape from the Vesuvian lava have been observed to deposit common salt.* The emission of free muriatic acid gas in great quantities favours the theory of the decomposition of the salt contained in sea water. It has been objected, however, that M. Boussingault did not meet with this gas in his late examination of the elastic fluids evolved from the volcanos of equatorial America ; which only give out aqueous vapour (in very large quantity), carbonic acid gas, sulphurous acid gas, and sometimes fumes of sulphur.†

But in reply Dr. Daubeny has remarked, that muriatic acid may have ceased to be disengaged, because the volcanic action has become languid in equatorial

* Davy, Phil. Trans. 1828, p. 244.

† Ann. de Chim. et de Phys. tom. lii. p. 181.

America. Sea-water may no longer obtain admission; or the heat may be inadequate to cause the union of the alkali of the sea salt with the earths present, or, if generated, it may be prevented from rising to the crater by combining with calcareous rocks through which it has to pass.*

M. Gay Lussac, while he avows his opinion that the decomposition of water contributes largely to volcanic action, calls attention, nevertheless, to the fact, that hydrogen has not been detected in a separate form among the gaseous products of volcanos; nor can it, he says, be present; for, in that case, it would be inflamed in the air by the red-hot stones thrown out during an eruption. Dr. Davy, also, in his account of Graham Island, says, "I watched when the lightning was most vivid; and the eruption of the greatest degree of violence, to see if there was any inflammation occasioned by this natural electric spark — any indication of the presence of inflammable gas; but in vain."†

May not the hydrogen, Gay Lussac inquires, be combined with chlorine, and produce muriatic acid? for this gas has been observed to be evolved from Vesuvius — and the chlorine may have been derived from sea salt; which was, in fact, extracted by simple washing from the Vesuvian lava of 1822, in the proportion of nine per cent.‡ But it was answered, that Sir H. Davy's experiments had shown, that hydrogen is not combustible when mixed with muriatic acid gas; so that if muriatic gas was evolved in large quantities, the hydrogen might be present without

* Daubeny, Jam. Ed. New Phil. Journ. No. lii. p. 298.

† Phil. Trans., 1832, p. 240.

‡ Ann. de Chim. et de Phys., tom. xxii.

inflammation.* M. Abich, however, assures us, "that although it be true that vapour illuminated by incandescent lava has often been mistaken for flame," yet he clearly detected in the eruption of Vesuvius in 1834 the flame of hydrogen.†

M. Gay Lussac, in the memoir just alluded to, expresses doubt as to the presence of sulphurous acid; but the abundant disengagement of this gas during eruptions is now ascertained: and thus all difficulty in regard to the general absence of hydrogen in an inflammable state is removed; for, as Dr. Daubeny suggests, the hydrogen of decomposed water may unite with sulphur to form sulphuretted hydrogen gas, and this gas will then be mingled with the sulphurous acid as it rises to the crater. It is shown by experiment, that these gases mutually decompose each other when mixed where steam is present; part of the hydrogen of the one immediately uniting with the oxygen of the other to form water, while the excess of sulphurous acid alone escapes into the atmosphere. Sulphur is at the same time precipitated.

This explanation is sufficient, but it may also be observed that the flame of hydrogen would rarely be visible during an eruption; as that gas, when inflamed in a pure state, burns with a very faint blue flame, which even in the night could hardly be perceptible by the side of red hot and incandescent cinders. Its immediate conversion into water when inflamed in the atmosphere, might also account for its not appearing in a separate form.

Dr. Daubeny is of opinion that water containing

* Quart. Journ. of Science, 1823, p. 132. note by editor.

† Phénom. Géol., &c. p. 3.

atmospheric air may descend from the surface of the earth to the volcanic foci, and that the same process of combustion by which water is decomposed may deprive such subterranean air of its oxygen. In this manner he explains the great quantities of nitrogen evolved from volcanic vents, and thermal waters, and the fact that air disengaged from the earth in volcanic regions is either wholly or in part deprived of its oxygen.

Sir H. Davy, in his memoir on the "Phenomena of Volcanos," remarks, that there was every reason to suppose in Vesuvius the existence of a descending current of air; and he imagined that subterranean cavities which threw out large volumes of steam during the eruption, might afterwards, in the quiet state of the volcano, become filled with atmospheric air.* The presence of ammoniacal salts in volcanic emanations, and of ammonia in lava, favours greatly the notion of air as well as water being deoxidated in the interior of the earth.†

It has been alleged by Professor Bischoff that the slight specific gravity of the metals of the alkalies is fatal to Davy's hypothesis, for if the mean density of the earth, as determined by astronomers, surpass that of all kinds of rocks, these metals cannot exist, at least not in great quantities in the interior of the earth.‡ But Dr. Daubeny has shown, that if we take the united specific gravity of potassium, sodium, silicon, iron, and all the materials which, when united with oxygen, con-

* Phil. Trans. 1828.

† Ammonia is composed of hydrogen and nitrogen: or the elements of air without its oxygen. See Daubeny, Encyc. Metrop. Part 40.

‡ Jam. Ed. New Phil. Journ. No. li. p. 31.

stitute ordinary lava, and then compare their weight with lava of equal bulk, the difference is not very material, the specific gravity of the lava only exceeding by about one fourth that of the unoxidized metals. Besides, at great depths the metallic bases of the earths and alkalies may very probably be rendered heavier by pressure.*

To conclude this part of our inquiry, there appears no sound objection to the doctrine, that chemical changes, going on at various depths in the earth, may be the cause of volcanic action, and that the contact of water with the unoxidized metals of the earths and alkalies may give rise to the heat required. The hydrogen, evolved during the process of saturation, may, on coming afterwards in contact with the heated metallic oxides, reduce them again to metals ; and this circle of action may be one of the principal means by which internal heat, and the stability of the volcanic energy, are preserved.

Cause of volcanic eruptions. — The most probable causes of a volcanic outburst at the surface have been in a great degree anticipated in the preceding speculations on the liquefaction of rocks and the generation of gases. When a minute hole is bored in a tube filled with gas condensed into a liquid, the whole becomes instantly aërisome, or, as some writers have expressed it, "flashes into vapour," and often bursts the tube. Such an experiment may represent the mode in which gaseous matter may rush through a rent in the rocks, and continue to escape for days or weeks through a small orifice, with an explosive power sufficient to

* See Daubeny's Reply to Bischoff, Jam. Ed. New Phil. Journ. No. lii. p. 291. ; and note in No. liii. p. 158.

reduce every substance which opposes its passage into small fragments or even dust. Lava may be propelled upwards at the same time, and ejected in the form of scoriæ. In some places, where the fluid lava lies at the bottom of a deep fissure, communicating, on the one hand, with the surface, and on the other with a cavern in which a considerable body of vapour has been formed, there may be an efflux of lava, followed by the escape of gas. Eruptions often commence and close with the discharge of vapour: and, when this is the case, the next outburst may be expected to take place by the same vent, for the concluding evolution of elastic fluids will keep open the duct, and leave it unobstructed.

The breaking out of lava from the side or base of a lofty cone, rather than from the summit, may be attributed to the hydrostatic pressure to which the flanks of the mountain are exposed, when the column of lava has risen to a great height. If, before it has reached the top, there should happen to be a stoppage of the main duct, the upward pressure of the ascending column of gas and lava may be sufficient to burst a lateral opening.

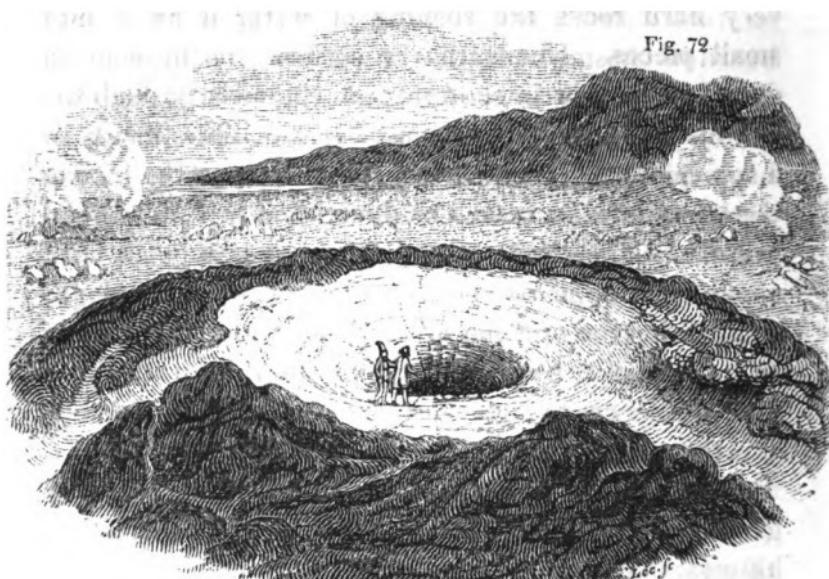
Geysers of Iceland.—As aqueous vapour constitutes the most abundant of the aërisform products of volcanos in eruption, it may be well to consider attentively a case in which steam is exclusively the moving power—that of the Geysers of Iceland. These intermittent hot springs occur in a district situated in the south-western division of Iceland, where nearly one hundred of them are said to break out within a circle of two miles. They rise through a thick current of lava, which may perhaps have flowed from Mount Hecla, the summit of that volcano being seen from the spot at the distance of more than thirty miles.

In this district, the rushing of water is sometimes heard in chasms beneath the surface ; for here, as on Etna, rivers flow in subterranean channels through the porous and cavernous lavas. It has more than once happened, after earthquakes, that some of the boiling fountains have increased or diminished in violence and volume, or entirely ceased, or that new ones have made their appearance — changes which may be explained by the opening of new rents and the closing of pre-existing fissures. It has often been reported that the powers of the Geysers are, upon the whole, on the decline ; but the description given by Mr. Barrow, jun. of the eruptions in 1834, agrees very closely with that of Sir J. Banks, written more than 60 years before.*

Few of the Geysers play longer than five or six minutes at a time, and the intervals between their eruptions are for the most part very irregular. The great Geyser rises out of a spacious basin at the summit of a circular mound composed of siliceous incrustations deposited from the spray of its waters. The diameter of this basin, in one direction, is fifty-six feet, and forty-six in another. (See fig. 72.)

In the centre is a pipe seventy-eight feet in perpendicular depth, and from eight to ten feet in diameter, but gradually widening, as it rises into the basin. The inside of the basin is whitish, consisting of a siliceous crust, and perfectly smooth, as are likewise two small channels on the sides of the mound, down which the water escapes when the bowl is filled to the margin. The circular basin is sometimes empty, as represented in the following sketch ; but is usually filled with beauti-

* See Barrow's visit to Iceland, ch. vi. 1834.



*View of the Crater of the great Geyser in Iceland. **

fully transparent water in a state of ebullition. During the rise of the boiling water in the pipe, especially when the ebullition is most violent, and when the water is thrown up in jets, subterranean noises are heard, like the distant firing of cannon, and the earth is slightly shaken. The sound then increases and the motion becomes more violent, till at length a column of water is thrown up, with loud explosions, to the height of one or two hundred feet. After playing for a time, like an artificial fountain, and giving off great clouds of vapour, the pipe or tube is emptied; and a column of steam rushing up with amazing force and a thundering noise, terminates the eruption.

If stones are thrown into the crater, they are instantly ejected; and such is the explosive force, that

* Reduced from a sketch given by W. J. Hooker, Esq., in his Tour in Iceland, vol. i. p. 149.

very hard rocks are sometimes shivered by it into small pieces. Henderson found that by throwing a great quantity of large stones into the pipe of Strockr, one of the Geysers, he could bring on an eruption in a few minutes.* The fragments of stone, as well as the boiling water, were thrown in that case to a much greater height than usual. After the water had been ejected, a column of steam continued to rush up with a deafening roar for nearly an hour; but the Geyser, as if exhausted by this effort, did not send out a fresh eruption when its usual interval of rest had elapsed.

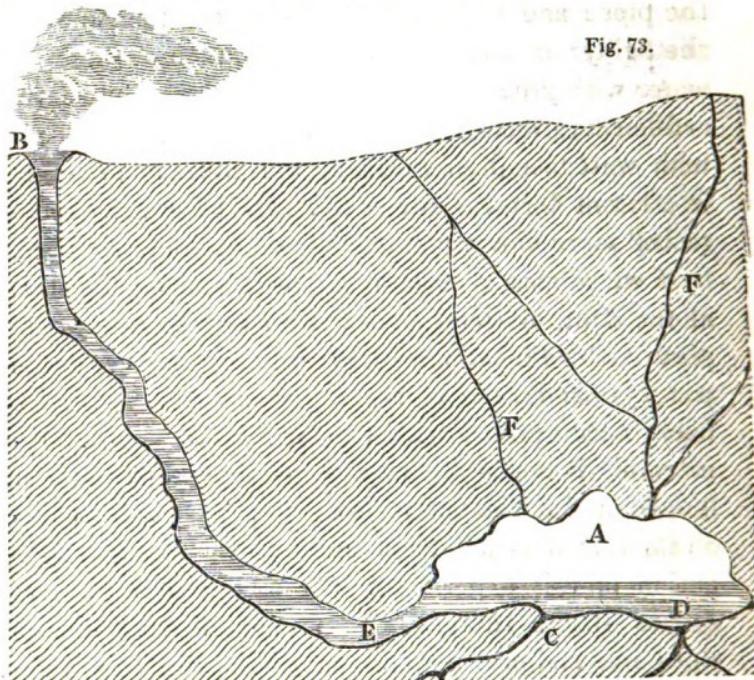
Among the different theories proposed to account for these phenomena, I shall first mention one suggested by Sir J. Herschel. An imitation of these jets, he says, may be produced on a small scale, by heating red-hot the stem of a tobacco pipe, filling the bowl with water, and so inclining the pipe as to let the water run through the stem. Its escape, instead of taking place in a continued stream, is then performed by a succession of violent explosions, at first of steam alone, then of water mixed with steam; and, as the pipe cools, almost wholly of water. At every such paroxysmal escape of the water, a portion is driven back, accompanied with steam, into the bowl. The intervals between the explosions depend on the heat, length, and inclination of the pipe; their continuance, on its thickness and conducting power.† The application of this experiment to the Geysers merely requires that a subterranean stream, flowing through the pores and crevices of lava, should suddenly reach a fissure, in which the rock is red-hot, or nearly so. Steam would immediately be formed, which, rushing

* Journal of a Residence in Iceland, p. 74.

† MS. read to Geol. Soc. of London, Feb. 29. 1832.

up the fissure, might force up water along with it to the surface, while, at the same time, part of the steam might drive back the water of the supply for a certain distance towards its source. And when, after the space of some minutes, the steam was all condensed, the water would return, and a repetition of the phenomena take place.

There is, however, another mode of explaining the action of the Geyser, perhaps more probable than that above described. Suppose water percolating from the surface of the earth to penetrate into the subterranean cavity A D (Fig. 73.) by the fissures F F, while, at the



*Supposed reservoir and pipe of a Geyser in Iceland.**

same time steam, at an extremely high temperature,

* From Sir George Mackenzie's Iceland.

such as is commonly given out from the rents of lava currents during congelation, emanates from the fissures C. A portion of the steam is at first condensed into water, while the temperature of the water is raised by the latent heat thus evolved, till, at last, the lower part of the cavity is filled with boiling water and the upper with steam under high pressure. The expansive force of the steam becomes, at length, so great, that the water is forced up the fissure or pipe E B, and runs over the rim of the basin. When the pressure is thus diminished, the steam in the upper part of the cavity A expands, until all the water D is driven into the pipe ; and when this happens, the steam, being the lighter of the two fluids, rushes up through the water with great velocity. If the pipe be choked up artificially, even for a few minutes, a great increase of heat must take place ; for it is prevented from escaping in a latent form in steam ; so that the water is made to boil more violently, and this brings on an eruption.

If we suppose that large subterranean cavities exist at the depth of some miles below the surface of the earth, in which melted lava accumulates, and that water penetrates into these, the steam thus generated may press upon lava and force it up the duct of a volcano, in the same manner as a column of water is driven up the pipe of a Geyser.

Causes of earthquakes — wave-like motion. — I shall now proceed to examine the manner in which the heat of the interior may give rise to earthquakes. One of the most common phenomena attending subterranean movements, is the undulatory motion of the ground. And this, says Michell, will seem less extraordinary, if we call to mind the extreme elasticity of the earth and the compressibility of even the most solid mate-

rials. Large districts, he suggests, may rest on fluid lava ; and, when this is disturbed, its motions may be propagated through the incumbent rocks. He also adds the following ingenious speculation : — “ As a small quantity of vapour almost instantly generated at some considerable depth below the surface of the earth will produce a vibratory motion, so a very large quantity (whether it be generated almost instantly, or in any small portion of time) will produce a wave-like motion. The manner in which this wave-like motion will be propagated may, in some measure, be represented by the following experiment : — Suppose a large cloth, or carpet (spread upon a floor), to be raised at one edge, and then suddenly brought down again to the floor ; the air under it, being by this means propelled, will pass along, till it escapes at the opposite side, raising the cloth in a wave all the way as it goes. In like manner, a large quantity of vapour may be conceived to raise the earth in a wave, as it passes along between the strata, which it may easily separate in a horizontal direction, there being little or no cohesion between one stratum and another. The part of the earth that is first raised, being bent from its natural form, will endeavour to restore itself by its elasticity ; and the parts next to it being to have their weight supported by the vapour, which will insinuate itself under them, will be raised in their turn, till it either finds some vent, or is again condensed by the cold into water, and by that means prevented from proceeding any farther.” *

To this hypothesis of Michell it has been objected,

* On the Cause and Phenomena of Earthquakes, Phil. Trans., vol. li. sect. 58. 1760.

with some reason, that the wave-like movements of the surface of the land during earthquakes, though violent, are on a very minute scale; as appears from the account of tall trees touching the ground with their tops, and then resuming their erect position, the sea-sickness experienced by spectators, and other phenomena, clearly indicating that the radius of each superficial curvature is very small. It has been suggested, that a vibratory jar may be produced at a considerable depth by the sudden fracture of the solid crust, and that the vibrations may be propagated upwards through a mass of rock several thousand feet, or several miles, thick. The first vibration which reaches the surface will lift up the soil, and then allow it to sink again, immediately after which another which may have radiated from the same deep-seated point may arrive at a contiguous spot on the surface, and cause a similar rise and fall, and so others in succession giving rise to a progressive motion of the ground very similar in appearance to a wave of the sea.

The facility with which all the particles of a solid mass can be made to vibrate, may be illustrated, says Gay Lussac, by many familiar examples. If we apply the ear to one end of a long wooden beam, and listen attentively when the other end is struck by a pin's head, we hear the shock distinctly; which shows that every fibre throughout the whole length has been made to vibrate. The rattling of carriages on the pavement shakes the largest edifices; and in the quarries underneath some quarters in Paris, it is found that the movement is communicated through a considerable thickness of rock.*

* Ann. de Ch. et de Ph., tom. xxii. p. 428.

The rending and upheaving of continental masses are operations which are not difficult to explain, when we are once convinced that heat, of sufficient power not only to melt, but to reduce to a gaseous form a great variety of substances, is accumulated in certain parts of the interior. We see that elastic fluids are capable of projecting solid masses to immense heights in the air; and the volcano of Cotopaxi has been known to throw out, to the distance of eight or nine miles, a mass of rock about one hundred cubic yards in volume. When we observe these aërisform fluids rushing out from particular vents for months, or even years, continuously, what power may we not expect them to exert in other places, where they happen to be confined under an enormous weight of rock?

Liquid gases. — The experiments of Faraday and others have shown, within the last twelve years, that many of the gases, including all those which are most copiously disengaged from volcanic vents, as the carbonic, sulphurous, and muriatic acids, may be condensed into liquids by pressure. At temperatures of from 30° to 50° F., the pressure required for this purpose varies from fifteen to fifty atmospheres; and this amount of pressure we may regard as very insignificant in the operations of nature. A column of Vesuvian lava that would reach from the lip of the crater to the level of the sea, must be equal to about three hundred atmospheres; so that, at depths which may be termed moderate in the interior of the crust of the earth, the gases may be condensed into liquids, even at very high temperatures. The method employed to reduce some of these gases to a liquid state is, to confine the materials, from the mutual action of which they are evolved, in tubes hermetically sealed, so that

the accumulated pressure of the vapour, as it rises and expands, may force some part of it to assume the liquid state. A similar process may, and indeed must, frequently take place in subterranean caverns and fissures, or even in the pores and cells of many rocks; by which means, a much greater store of expansive power may be *packed* into a small space than could happen if these vapours had not the property of becoming liquid. For, although the gas occupies much less room in a liquid state, yet it exerts exactly the same pressure upon the sides of the containing cavity as if it remained in the form of vapour.

If a tube, whether of glass or other materials, filled with condensed gas, have its temperature slightly raised, it will often burst; for a slight increment of heat causes the elasticity of the gas to increase in a very high ratio. We have only to suppose certain rocks permeated by these liquid gases (as porous strata are sometimes filled with water), to have their temperature raised some hundred degrees, and we obtain a power capable of lifting superincumbent masses of almost any conceivable thickness: while, if the depth at which the gas is confined be great, there is no reason to suppose that any other appearances would be witnessed by the inhabitants of the surface than vibratory movements and rents, from which no vapour might escape. In making their way through fissures a very few miles only in length, or in forcing a passage through soft yielding strata, the vapours may be cooled and absorbed by water. For water has a strong affinity to several of the gases; and will absorb large quantities, with a very slight increase of volume. In this manner, the heat or the volume of springs may be augmented, and their mineral properties made to vary.

Connexion between the state of the atmosphere and earthquakes. — The inhabitants of Stromboli, who are mostly fishermen, are said to make use of that volcano as a weather-glass, the eruptions being comparatively feeble when the sky is serene, but increasing in turbulence during tempestuous weather, so that in winter the island often seems to shake from its foundations. Mr. Scrope, after calling attention to these and other analogous facts, first started the idea, that the diminished pressure of the atmosphere, the concomitant of stormy weather, may modify the intensity of the volcanic action. He suggests, for example, that where liquid lava communicates with the surface, as in the crater of Stromboli, it may rise or fall in the vent on the same principle as mercury in a barometer; because the ebullition or expansive power of the steam contained in the lava would be checked by every increase, and augmented by every diminution of weight. In like manner, if a bed of liquid lava be confined at an immense depth below the surface, its expansive force may be counteracted partly by the weight of the incumbent rocks, and also in part by atmospheric pressure acting contemporaneously on a vast superficial area. In that case if the upheaving force increase gradually in energy it will at length be restrained by only the slightest degree of superiority in the antagonist or repressive power, and then the equilibrium may be suddenly destroyed by any cause, such as an ascending draught of air, which is capable of depressing the barometer. In this manner we may account for the remarkable coincidence so frequently observed between the state of the weather and subterranean commotions, although it must be admitted that earthquakes and volcanic eruptions re-act in their turn upon the atmosphere, so that

disturbances of the latter are generally the consequences rather than the forerunners of volcanic disturbances.*

Permanent elevation and subsidence.—It is easy to conceive that the shattered rocks may assume an arched form during a convulsion, so that the country above may remain permanently upheaved. In other cases gas may drive before it masses of liquid lava, which may thus be injected into newly opened fissures. The gas having then obtained more room, by the forcing up of the incumbent rocks, may remain at rest; while the lava congealing in the rents, may afford a solid foundation for the newly raised district.

Experiments have recently been made in America, by Colonel Totten, to ascertain the ratio according to which some of the stones commonly used in architecture expand with given increments of heat.† It was found impossible, in a country where the annual variation of temperature was more than 90° F., to make a coping of stones, five feet in length, in which the joints should fit so tightly as not to admit water between the stone and the cement; the annual contraction and expansion of the stones causing, at the junctions, small crevices, the width of which varied with the nature of the rock. It was ascertained that fine-grained granite expanded with 1° F. at the rate of .000004825; white crystalline marble .000005668; and red sandstone .000009532, or about twice as much as granite.

Now, according to this law of expansion, a mass of sandstone, a mile in thickness, which should have its temperature raised 200° F., would lift a super-

* Scrope on Volcanos, pp. 58—60.

† Silliman's American Journ., vol. xxii. p. 136. The application of these results to the theory of earthquakes, was first suggested to me by Mr. Babbage.

imposed layer of rock to the height of ten feet above its former level. But, suppose a part of the earth's crust, one hundred miles in thickness and equally expansible, to have its temperature raised 600° or 800°, this might produce an elevation of between two and three thousand feet. The cooling of the same mass might afterwards cause the overlying rocks to sink down again and resume their original position. By such agency we might explain the gradual rise of Scandinavia or the subsidence of Greenland, if this last phenomenon should also be established as a fact on further inquiry.

It is also possible that as the clay in Wedgwood's pyrometer contracts, by giving off its water, and then, by incipient vitrification; so, large masses of argillaceous strata in the earth's interior may shrink, when subjected to heat and chemical changes, and allow the incumbent rocks to subside gradually. It may frequently happen that fissures of great extent may be formed in rocks simply by the unequal expansion of a continuous mass, heated in one part, while in another it remains at a comparatively low temperature. The sudden subsidence of land may also be occasioned by subterranean caverns giving way, when gases are condensed, or when they escape through newly-formed crevices. The subtraction, moreover, of matter from certain parts of the interior, by the flowing of lava, and of mineral springs, must, in the course of ages, cause vacuities below, so that the undermined surface may at length fall in.

The balance of dry land, how preserved. — In the present state of our knowledge, we cannot pretend to estimate the average number of earthquakes which may happen in the course of a single year. As the

area of the ocean is nearly three times that of the land, it is probable that about three submarine earthquakes may occur for one exclusively continental; and when we consider the great frequency of slight movements in certain districts, we can hardly suppose that a day ever passes without one or more shocks being experienced in some part of the globe. We have also seen that in Sweden, and other countries, changes in the relative level of sea and land may take place without commotion, and these perhaps produce the most important geographical and geological changes; for the position of land may be altered to a greater amount by an elevation or depression of one inch over a vast area, than by the sinking of a more limited tract, such as the forest of Aripao, to the depth of many fathoms at once.*

It must be evident, from the historical details above given, that the force of subterranean movement, whether intermittent or continuous, whether with or without disturbance, does not operate at random, but is developed in certain regions only; and although the alterations produced during the time required for the occurrence of a few volcanic eruptions may be inconsiderable, we can hardly doubt that, during the ages necessary for the formation of large volcanic cones, composed of thousands of lava currents, shoals might be converted into lofty mountains, and low lands into deep seas.

In a former chapter, I have stated that aqueous and igneous agents may be regarded as antagonist forces; the aqueous labouring incessantly to reduce the inequalities of the earth's surface to a level, while the igneous are equally active in renewing the unevenness

* See p. 322.

of the surface.* By some geologists it has been thought that the levelling power of running water was opposed rather to the *elevating* force of earthquakes than to their action generally. This opinion is, however, untenable; for the sinking down of the bed of the ocean is one of the means by which the gradual submersion of land is prevented. The depth of the sea cannot be increased at any one point without a universal fall of the waters, nor can any partial deposition of sediment occur without the displacement of a quantity of water of equal volume, which will raise the sea, though in an imperceptible degree, even to the antipodes. The preservation, therefore, of the dry land may sometimes be effected by the subsidence of part of the earth's crust (that part, namely, which is covered by the ocean), and in like manner an upheaving movement must often tend to destroy land; for if it render the bed of the sea more shallow, it will displace a certain quantity of water, and thus tend to submerge low tracts.

Astronomers having proved that there has been no change in the diameter of the earth during the last two thousand years, we may assume it as probable, that the dimensions of the planet remain uniform.† If, then, we inquire in what manner the force of earthquakes must be regulated, in order to restore perpetually the inequalities of the surface which the levelling power of water tends to efface, it will be found, that the amount of depression must exceed that of elevation. It would be otherwise if the action of volcanos and mineral springs were suspended; for then the forcing outwards of the earth's envelope ought to be no more than equal to its sinking in.

* Book ii. chap. i.

† Book i. chap. viii.

To understand this proposition more clearly, it must be borne in mind, that the deposits of rivers and currents probably add as much to the height of lands which are rising, as they take from those which have risen. Suppose a large river to bring down sediment to a part of the ocean two thousand feet deep, and that the depth of this part is gradually reduced by the accumulation of sediment till only a shoal remains, covered by water at high tides; if now an upheaving force should uplift this shoal to the height of 2000 feet, the result would be a mountain 2000 feet high. But had the movement raised the same part of the bottom of the sea before the sediment of the river had filled it up; then, instead of changing a shoal into a mountain 2000 feet high, it would only have converted a deep sea into a shoal.

It appears, then, that the operations of the earthquake are often such as to cause the levelling power of water to counteract itself; and, although the idea may appear paradoxical, we may be sure, wherever we find hills and mountains composed of stratified deposits, that such inequalities of the surface would have had no existence if water, at some former period, had not been labouring to reduce the earth's surface to one level.

But, besides the transfer of matter by running water from the continents to the ocean, there is a constant transportation from below upwards, by mineral springs and volcanic vents. As mountain masses are, in the course of ages, created by the pouring forth of successive streams of lava, so stratified rocks, of great extent, originate from the deposition of carbonate of lime, and other mineral ingredients, with which springs are impregnated. The surface of the land, and por-

tions of the bottom of the sea, being thus raised, the external accessions due to these operations would cause the dimensions of the planet to enlarge continually, if the amount of depression of the earth's crust were no more than equal to the elevation. In order, therefore, that the mean diameter of the earth should remain uniform, and the unevenness of the surface be preserved, it is necessary that the amount of subsidence should be in excess. And such a predominance of depression is far from improbable, on mechanical principles, since every upheaving movement must be expected either to produce caverns in the mass below, or to cause some diminution of its density. Vacuities must, also, arise from the subtraction of the matter poured out from volcanos and mineral springs, or from the contraction of argillaceous masses by subterranean heat ; and the foundations having been thus weakened, the earth's crust, shaken and rent by reiterated convulsions, must, in the course of time, fall in.

If we embrace these views, important geological consequences will follow ; since, if there be, upon the whole, more subsidence than elevation, the average depth to which former surfaces have sunk beneath their original level must exceed the height which ancient marine strata have attained above the sea. If, for example, marine strata, about the age of our chalk and green-sand, have been lifted up in Europe to an extreme height of more than eleven thousand feet, and a mean elevation of some hundreds, we may conclude that certain parts of the surface, which existed when those strata were deposited, have sunk to an extreme depth of *more than* eleven thousand feet below their

original level, and to a mean depth of *more than* a few hundreds.

In regard to faults, also, we must infer, according to the hypothesis now proposed, that a greater number have arisen from the sinking down than from the elevation of rocks.

To conclude: it seems to be rendered probable, by the views above explained, that the constant repair of the land, and the subserviency of our planet to the support of terrestrial as well as aquatic species, are secured by the elevating and depressing power of causes acting in the interior of the earth; which, although so often the source of death and terror to the inhabitants of the globe—visiting in succession every zone, and filling the earth with monuments of ruin and disorder—are nevertheless the agents of a conservative principle above all others essential to the stability of the system.

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BOOK III.

CHAPTER I.

CHANGES OF THE ORGANIC WORLD NOW IN PROGRESS.

Division of the subject — Examination of the question, Whether species have a real existence in nature? — Importance of this question in geology — Sketch of Lamarck's arguments in favour of the transmutation of species, and his conjectures respecting the origin of existing animals and plants — His theory of the transformation of the orang-outang into the human species.

THE last book was occupied with the consideration of the changes brought about on the earth's surface, within the period of human observation, by inorganic agents; such, for example, as rivers, marine currents, volcanos, and earthquakes. But there is another class of phenomena relating to the organic world, which have an equal claim on our attention, if we desire to obtain possession of all the preparatory knowledge respecting the existing course of nature, which may be available in the interpretation of geological monuments. It appeared from our preliminary sketch of the progress of the science, that the most lively interest was excited

among its earlier cultivators, by the discovery of the remains of animals and plants in the interior of mountains frequently remote from the sea. Much controversy arose respecting the nature of these remains, the causes which may have brought them into so singular a position, and the want of a specific agreement between them and known animals and plants. To qualify ourselves to form just views on these curious questions, we must first study the present condition of the animate creation on the globe.

This branch of our inquiry naturally divides itself into two parts: first, we may examine the vicissitudes to which species are subject; secondly, the processes by which certain individuals of these species occasionally become fossil. The first of these divisions will lead us, among other topics, to inquire first, whether species have a real and permanent existence in nature? or whether they are capable, as some naturalists pretend, of being indefinitely modified in the course of a long series of generations? Secondly, whether, if species have a real existence, the individuals composing them have been derived originally from many similar stocks, or each from one only, the descendants of which have spread themselves gradually from a particular point over the habitable lands and waters? Thirdly, how far the duration of each species of animal and plant is limited by its dependence on certain fluctuating and temporary conditions in the state of the animate and inanimate world? Fourthly, whether there be proofs of the successive extermination of species in the ordinary course of nature, and whether there be any reason for conjecturing that new animals and plants are created from time to time, to supply their place?

Whether species have a real existence in nature. — Before we can advance a step in our proposed inquiry, we must be able to define precisely the meaning which we attach to the term species. This is even more necessary in geology than in the ordinary studies of the naturalist; for they who deny that such a thing as a species exists, concede nevertheless that a botanist or zoologist may reason as if the specific character were constant, because they confine their observations to a brief period of time. Just as the geographer, in constructing his maps from century to century, may proceed as if the apparent places of the fixed stars remained absolutely the same, and as if no alteration were brought about by the precession of the equinoxes; so, it is said, in the organic world, the stability of a species may be taken as absolute, if we do not extend our views beyond the narrow period of human history; but let a sufficient number of centuries elapse, to allow of important revolutions in climate, physical geography, and other circumstances, and the characters, say they, of the descendants of common parents may deviate indefinitely from their original type.

Now, if these doctrines be tenable, we are at once presented with a principle of incessant change in the organic world; and no degree of dissimilarity in the plants and animals which may formerly have existed, and are found fossil, would entitle us to conclude that they may not have been the prototypes and progenitors of the species now living. Accordingly M. Geoffroy St. Hilaire has declared his opinion, that there has been an uninterrupted succession in the animal kingdom, effected by means of generation, from the earliest ages of the world up to the present day, and that the ancient animals whose remains have been

preserved in the strata, however different, may nevertheless have been the ancestors of those now in being. This notion is not very generally received, but we are not warranted in assuming the contrary, without fully explaining the data and reasoning by which it may be refuted.

I shall begin by stating as concisely as possible all the facts and ingenious arguments by which the theory has been supported; and for this purpose I cannot do better than offer the reader a rapid sketch of Lamarck's statement of the proofs which he regards as confirmatory of the doctrine, and which he has derived partly from the works of his predecessors and in part from original investigations.

His proofs and inferences will be best considered in the order in which they appear to have influenced his mind, and I shall then point out some of the results to which he was led while boldly following out his principles to their legitimate consequences.

Lamarck's arguments in favour of the transmutation of species. — The name of species, observes Lamarck, has been usually applied to "every collection of similar individuals produced by other individuals like themselves." * This definition, he admits, is correct; because every living individual bears a very close resemblance to those from which it springs. But this is not all which is usually implied by the term species; for the majority of naturalists agree with Linnæus in supposing that all the individuals propagated from one stock have certain distinguishing characters in common, which will never vary, and which have remained the same since the creation of each species.

* Phil. Zool. tom. i. p. 54.

In order to shake this opinion, Lamarck enters upon the following line of argument: — The more we advance in the knowledge of the different organized bodies which cover the surface of the globe, the more our embarrassment increases, to determine what ought to be regarded as a species, and still more how to limit and distinguish genera. In proportion as our collections are enriched, we see almost every void filled up, and all our lines of separation effaced; we are reduced to arbitrary determinations, and are sometimes fain to seize upon the slight differences of mere varieties, in order to form characters for what we choose to call a species; and sometimes we are induced to pronounce individuals but slightly differing, and which others regard as true species, to be varieties.

The greater the abundance of natural objects assembled together, the more do we discover proofs that every thing passes by insensible shades into something else: that even the more remarkable differences are evanescent, and that nature has for the most part, left us nothing at our disposal for establishing distinctions, save trifling, and, in some respects, puerile particularities.

We find that many genera amongst animals and plants are of such an extent, in consequence of the number of species referred to them, that the study and determination of these last has become almost impracticable. When the species are arranged in a series, and placed near to each other, with due regard to their natural affinities, they each differ in so minute a degree from those next adjoining, that they almost melt into each other, and are in a manner confounded together. If we see isolated species, we may pre-

sume the absence of some more closely connected, and which have not yet been discovered. Already are there genera, and even entire orders —nay, whole classes, which present an approximation to the state of things here indicated.

If, when species have been thus placed in a regular series, we select one, and then, making a leap over several intermediate ones, we take a second, at some distance from the first, these two will, on comparison, be seen to be very dissimilar: and it is in this manner that every naturalist begins to study the objects which are at his own door. He then finds it an easy task to establish generic and specific distinctions; and it is only when his experience is enlarged, and when he has made himself master of the intermediate links that his difficulties and ambiguities begin. But while we are thus compelled to resort to trifling and minute characters in our attempt to separate species, we find a striking disparity between individuals which we know to have descended from a common stock; and these newly acquired peculiarities are regularly transmitted from one generation to another, constituting what are called *races*.

From a great number of facts, continues the author, we learn that in proportion as the individuals of one of our species change their situation, climate, and manner of living, they change also, by little and little, the consistence and proportions of their parts, their form, their faculties, and even their organization, in such a manner that every thing in them comes at last to participate in the mutations to which they have been exposed. Even in the same climate, a great difference of situation and exposure causes individuals to vary; but if these individuals continue to live and to be repro-

duced under the same difference of circumstances, distinctions are brought about in them which become in some degree essential to their existence. In a word, at the end of many successive generations, these individuals, which originally belonged to another species, are transformed into a new and distinct species.*

Thus, for example, if the seeds of a grass, or any other plant which grows naturally in a moist meadow, be accidentally transported, first to the slope of some neighbouring hill, where the soil, although at a greater elevation, is damp enough to allow the plant to live; and if, after having lived there, and having been several times regenerated, it reaches by degrees the drier and almost arid soil of a mountain declivity, it will then, if it succeeds in growing, and perpetuates itself for a series of generations, be so changed that botanists who meet with it will regard it as a particular species.† The unfavourable climate in this case, deficiency of nourishment, exposure to the winds, and other causes, give rise to a stunted and dwarfish race, with some organ more developed than others, and having proportions often quite peculiar.

What nature brings about in a great lapse of time, we occasion suddenly by changing the circumstances in which a species has been accustomed to live. All are aware that vegetables taken from their birth-place, and cultivated in gardens, undergo changes which render them no longer recognizable as the same plants. Many which were naturally hairy become smooth, or nearly so; a great number of such as were creepers and trailed along the ground, rear their stalks and grow erect. Others lose their thorns or asperities;

* Phil. Zool. tom. i. p. 62.

† Ibid.

others, again, from the ligneous state which their stem possessed in hot climates, where they were indigenus, pass to the herbaceous ; and, among them, some which were perennials become mere annuals. So well do botanists know the effects of such changes of circumstances, that they are averse to describe species from garden specimens, unless they are sure that they have been cultivated for a very short period.

“ Is not the cultivated wheat ” (*Triticum sativum*), asks Lamarck, “ a vegetable brought by man into the state in which we now see it ? Let any one tell me in what country a similar plant grows wild, unless where it has escaped from cultivated fields ? Where do we find in nature our cabbages, lettuces, and other culinary vegetables, in the state in which they appear in our gardens ? Is it not the same in regard to a great quantity of animals which domesticity has changed or considerably modified ? ” * Our domestic fowls and pigeons are unlike any wild birds. Our domestic ducks and geese have lost the faculty of raising themselves into the higher regions of the air, and crossing extensive countries in their flight, like the wild ducks and wild geese from which they were originally derived. A bird which we breed in a cage cannot, when restored to liberty, fly like others of the same species which have been always free. This small alteration of circumstances, however, has only diminished the power of flight, without modifying the form of any part of the wings. But when individuals of the same race are retained in captivity during a considerable length of time, the form even of their parts is gradually made to differ, especially if climate, nourishment, and other circumstances be also altered.

* Phil. Zool. tom. i. p. 227.

The numerous races of dogs which we have produced by domesticity are nowhere to be found in a wild state. In nature we should seek in vain for mastiffs, harriers, spaniels, greyhounds, and other races, between which the differences are sometimes so great that they would be readily admitted as specific between wild animals ; “ yet all these have sprung originally from a single race, at first approaching very near to a wolf, if, indeed, the wolf be not the true type which at some period or other was domesticated by man.”

Although important changes in the nature of the places which they inhabit modify the organization of animals as well as vegetables ; yet the former, says Lamarck, require more time to complete a considerable degree of transmutation ; and, consequently, we are less sensible of such occurrences. Next to a diversity of the medium in which animals or plants may live, the circumstances which have most influence in modifying their organs are differences in exposure, climate, the nature of the soil, and other local particulars. These circumstances are as varied as are the characters of the species, and, like them, pass by insensible shades into each other, there being every intermediate gradation between the opposite extremes. But each locality remains for a very long time the same, and is altered so slowly that we can only become conscious of the reality of the change by consulting geological monuments, by which we learn that the order of things which now reigns in each place has not always prevailed, and by inference anticipate that it will not always continue the same.*

Every considerable alteration in the local circum-

* Phil. Zool. tom. i. p. 232.

stances in which each race of animals exists causes a change in their wants, and these new wants excite them to new actions and habits. These actions require the more frequent employment of some parts before but slightly exercised, and then greater development follows as a consequence of their more frequent use. Other organs no longer in use are impoverished and diminished in size, nay, are sometimes entirely annihilated, while in their place new parts are insensibly produced for the discharge of new functions.*

I must here interrupt the author's argument, by observing, that no positive fact is cited to exemplify the substitution of some *entirely new* sense, faculty, or organ, in the room of some other suppressed as useless. All the instances adduced go only to prove that the dimensions and strength of members and the perfection of certain attributes may, in a long succession of generations, be lessened and enfeebled by disuse ; or, on the contrary, be matured and augmented by active exertion ; just as we know that the power of scent is feeble in the greyhound, while its swiftness of pace and its acuteness of sight are remarkable — that the harrier and stag-hound, on the contrary, are comparatively slow in their movements, but excel in the sense of smelling.

It was necessary to point out to the reader this important chasm in the chain of evidence, because he might otherwise imagine that I had merely omitted the illustrations for the sake of brevity, but the plain truth is, that there were no examples to be found ; and when Lamarck talks “of the efforts of internal senti-

*. Phil. Zool. tom. i. p.234.

ment," "the influence of subtle fluids," and "acts of organization," as causes whereby animals and plants may acquire *new organs*, he substitutes names for things; and, with a disregard to the strict rules of induction, resorts to fictions, as ideal as the "plastic virtue," and other phantoms, of the geologists of the middle ages.

It is evident that, if some well-authenticated facts could have been adduced to establish one complete step in the process of transformation, such as the appearance, in individuals descending from a common stock, of a sense or organ entirely new, and a complete disappearance of some other enjoyed by their progenitors, time alone might then be supposed sufficient to bring about any amount of metamorphosis. The gratuitous assumption, therefore, of a point so vital to the theory of transmutation, was unpardonable on the part of its advocate.

But to proceed with the system: it being assumed as an undoubted fact, that a change of external circumstances may cause one organ to become entirely obsolete, and a new one to be developed, such as never before belonged to the species, the following proposition is announced, which, however staggering and absurd it may seem, is logically deduced from the assumed premises. It is not the organs, or, in other words, the nature and form of the parts of the body of an animal, which have given rise to its habits, and its particular faculties; but, on the contrary, its habits, its manner of living, and those of its progenitors, have in the course of time determined the form of its body, the number and condition of its organs, in short, the faculties which it enjoys. Thus otters, beavers, water-fowl, turtles, and frogs, were not made web-footed in

order that they might swim ; but their wants having attracted them to the water in search of prey, they stretched out the toes of their feet to strike the water and move rapidly along its surface. By the repeated stretching of their toes, the skin which united them at the base acquired a habit of extension, until, in the course of time, the broad membranes which now connect their extremities were formed.

In like manner, the antelope and the gazelle were not endowed with light agile forms, in order that they might escape by flight from carnivorous animals ; but, having been exposed to the danger of being devoured by lions, tigers, and other beasts of prey, they were compelled to exert themselves in running with great celerity ; a habit which, in the course of many generations, gave rise to the peculiar slenderness of their legs, and the agility and elegance of their forms.

The camelopard was not gifted with a long flexible neck because it was destined to live in the interior of Africa, where the soil was arid and devoid of herbage ; but, being reduced by the nature of that country to support itself on the foliage of lofty trees, it contracted a habit of stretching itself up to reach the high boughs, until its neck became so elongated that it could raise its head to the height of twenty feet above the ground.

Another line of argument is then entered upon, in further corroboration of the instability of species. In order, it is said, that individuals should perpetuate themselves unaltered by generation, those belonging to one species ought never to ally themselves to those of another ; but such sexual unions do take place, both among plants and animals ; and although the offspring of such irregular connexions are usually sterile, yet such is not always the case. Hybrids have some-

times proved prolific, where the disparity between the species was not too great ; and by this means alone, says Lamarck, varieties may gradually be created by near alliances, which would become races, and in the course of time would constitute what we term species.*

But if the soundness of all these arguments and inferences be admitted, we are next to inquire, what were the original types of form, organization, and instinct, from which the diversities of character, as now exhibited by animals and plants, have been derived ? We know that individuals which are mere varieties of the same species would, if their pedigree could be traced back far enough, terminate in a single stock ; so, according to the train of reasoning before described, the species of a genus, and even the genera of a great family, must have had a common point of departure. What, then, was the single stem from which so many varieties of form have rained ? Were there many of these, or are we to refer the origin of the whole animate creation, as the Egyptian priests did that of the universe, to a single egg ?

In the absence of any positive data for framing a theory on so obscure a subject, the following considerations were deemed of importance to guide conjecture.

In the first place, if we examine the whole series of known animals, from one extremity to the other, when they are arranged in the order of their natural relations, we find that we may pass progressively, or, at least, with very few interruptions, from beings of more simple to those of a more compound structure ; and, in proportion as the complexity of their organization increases, the number and dignity of their faculties

* Phil. Zool. p. 64.

increase also. Among plants, a similar approximation to a graduated scale of being is apparent. Secondly, it appears, from geological observations, that plants and animals of more simple organization existed on the globe before the appearance of those of more compound structure, and the latter were successively formed at more modern periods: each new race being more fully developed than the most perfect of the preceding era.

Of the truth of the last-mentioned geological theory, Lamarck seems to have been fully persuaded; and he also shows that he was deeply impressed with a belief prevalent amongst the older naturalists, that the primeval ocean invested the whole planet long after it became the habitation of living beings; and thus he was inclined to assert the priority of the types of marine animals to those of the terrestrial, so as to fancy, for example, that the testacea of the ocean existed first, until some of them, by gradual evolution, were *improved* into those inhabiting the land.

These speculative views had already been, in a great degree, anticipated by Demaillet in his *Telliamed*, and by several modern writers; so that the tables were completely turned on the philosophers of antiquity, with whom it was a received maxim, that created things were always most perfect when they came first from the hands of their Maker; and that there was a tendency to progressive deterioration in sublunary things when left to themselves —

————— *omnia fatis*
In pejus ruere, ac retrò sublapsa referri.

So deeply was the faith of the ancient schools of philosophy imbued with this doctrine, that, to check

this universal proneness to degeneracy, nothing less than the re-intervention of the Deity was thought adequate ; and it was held, that thereby the order, excellence, and pristine energy of the moral and physical world had been repeatedly restored.

But when the possibility of the indefinite modification of individuals descending from common parents was once assumed, as also the geological inference respecting the progressive development of organic life, it was natural that the ancient dogma should be rejected, or rather reversed, and that the most simple and imperfect forms and faculties should be conceived to have been the originals whence all others were developed. Accordingly, in conformity to these views, inert matter was supposed to have been first endowed with life ; until, in the course of ages, sensation was superadded to mere vitality : sight, hearing, and the other senses were afterwards acquired ; then instinct and the mental faculties ; until, finally, by virtue of the tendency of things to *progressive improvement*, the irrational was developed into the rational.

The reader, however, will immediately perceive that when all the higher order of plants and animals were thus supposed to be comparatively modern, and to have been derived in a long series of generations from those of more simple conformation, some further hypothesis became indispensable, in order to explain why, after an indefinite lapse of ages, there were still so many beings of the simplest structure. Why have the majority of existing creatures remained stationary throughout this long succession of epochs, while others have made such prodigious advances ? Why are there such multitudes of infusoria and polyps, or of confervæ and other cryptogamic plants ? Why, moreover, has

the process of development acted with such unequal and irregular force on those classes of beings which have been greatly perfected, so that there are wide chasms in the series ; gaps so enormous, that Lamarck fairly admits we can never expect to fill them up by future discoveries ?

The following hypothesis was provided to meet these objections. Nature, we are told, is not an intelligence, nor the Deity ; but a delegated power — a mere instrument — a piece of mechanism acting by necessity — an order of things constituted by the Supreme Being, and subject to laws which are the expressions of his will. This Nature is *obliged* to proceed gradually in all her operations ; she cannot produce animals and plants of all classes at once, but must always begin by the formation of the most simple kinds, and out of them elaborate the more compound, adding to them, successively, different systems of organs, and multiplying more and more their number and energy.

This Nature is daily engaged in the formation of the elementary rudiments of animal and vegetable existence, which correspond to what the ancients termed *spontaneous generation*. She is always beginning anew, day by day, the work of creation, by forming monads, or “rough draughts” (*ébauches*), which are the only living things she gives birth to *directly*.

There are distinct primary rudiments of plants and animals, and *probably* of each of the great divisions of the animal and vegetable kingdoms.* These are gradually developed into the higher and more perfect classes by the slow but unceasing agency of two influential principles : first, *the tendency to progressive*

* *Animaux sans Vert.* tom. i. p. 56. Introduction.

advancement in organization, accompanied by greater dignity in instinct, intelligence, &c.; secondly, *the force of external circumstances*, or of variations in the physical condition of the earth, or the mutual relations of plants and animals. For, as species spread themselves gradually over the globe, they are exposed from time to time to variations in climate, and to changes in the quantity and quality of their food; they meet with new plants and animals which assist or retard their development, by supplying them with nutriment, or destroying their foes. The nature, also, of each locality, is in itself fluctuating; so that, even if the relation of other animals and plants were invariable, the habits and organization of species would be modified by the influence of local revolutions.

Now, if the first of these principles, *the tendency to progressive development*, were left to exert itself with perfect freedom, it would give rise, says Lamarck, in the course of ages, to a graduated scale of being, where the most insensible transition might be traced from the simplest to the most compound structure, from the humblest to the most exalted degree of intelligence. But, in consequence of the perpetual interference of the *external causes* before mentioned, this regular order is greatly interfered with, and an approximation only to such a state of things is exhibited by the animate creation, the progress of some races being retarded by unfavourable, and that of others accelerated by favourable, combinations of circumstances. Hence, all kinds of anomalies interrupt the continuity of the plan; and chasms, into which whole genera or families might be inserted, are seen to separate the nearest existing portions of the series.

Lamarck's theory of the transformation of the orang-outang into the human species.—Such is the machinery of the Lamarckian system; but the reader will hardly, perhaps, be able to form a perfect conception of so complicated a piece of mechanism, unless it is exhibited in motion, so that we may see in what manner it can work out, under the author's guidance, all the extraordinary effects which we behold in the present state of the animate creation. I have only space for exhibiting a small part of the entire process by which a complete metamorphosis is achieved, and shall therefore, omit the mode by which, after a countless succession of generations, a small gelatinous body is transformed into an oak or an ape; passing on at once to the last grand step in the progressive scheme, by which the orang-outang, having been already evolved out of a monad, is made slowly to attain the attributes and dignity of man.

One of the races of quadrumanous animals which had reached the highest state of perfection, lost, by constraint of circumstances (concerning the exact nature of which tradition is unfortunately silent), the habit of climbing trees, and of hanging on by grasping the boughs with their feet as with hands. The individuals of this race being obliged, for a long series of generations, to use their feet exclusively for walking, and ceasing to employ their hands as feet, were transformed into bimanous animals, and what before were thumbs became mere toes, no separation being required when their feet were used solely for walking. Having acquired a habit of holding themselves upright, their legs and feet assumed, insensibly, a conformation fitted to support them in an erect attitude, till at last these

animals could no longer go on all-fours without much inconvenience.

The Angola orang (*Simia troglodytes*, Linn.) is the most perfect of animals; much more so than the Indian orang (*Simia Satyrus*), which has been called the orang-outang, although *both* are *very inferior* to man in corporeal powers and intelligence. These animals frequently hold themselves upright; but their organization has *not yet* been sufficiently modified to sustain them habitually in this attitude, so that the standing posture is very uneasy to them. When the Indian orang is compelled to take flight from pressing danger, he immediately falls down upon all-fours, showing clearly that this was the original position of the animal. Even in man, whose organization, in the course of a long series of generations, has advanced so much farther, the upright posture is fatiguing, and can be supported only for a limited time, and by aid of the contraction of many muscles. If the vertebral column formed the axis of the human body, and supported the head and all the other parts in equilibrium, then might the upright position be a state of repose: but, as the human head does not articulate in the centre of gravity, as the chest, belly, and other parts press almost entirely forward with their whole weight, and as the vertebral column reposes upon an oblique base, a watchful activity is required to prevent the body from falling. Children which have large heads and prominent bellies can hardly walk at the end even of two years; and their frequent tumbles indicate the natural tendency in man to resume the quadrupedal state.

Now, when so much progress had been made by the quadrumanous animals before mentioned, that they

could hold themselves habitually in an erect attitude, and were accustomed to a wide range of vision, and ceased to use their jaws for fighting and tearing, or for clipping herbs for food, their snout became gradually shorter, their incisor teeth became vertical, and the facial angle grew more open.

Among other ideas which the natural *tendency to perfection* engendered, the desire of ruling suggested itself, and this race succeeded at length in getting the better of the other animals, and made themselves masters of all those spots on the surface of the globe which best suited them. They drove out the animals which approached nearest them in organization and intelligence, and which were in a condition to dispute with them the good things of this world, forcing them to take refuge in deserts, woods, and wildernesses, where their multiplication was checked, and the progressive development of their faculties retarded; while, in the mean time, the dominant race spread itself in every direction, and lived in large companies, where new wants were successively created, exciting them to industry, and gradually perfecting their means and faculties.

In the supremacy and increased intelligence acquired by the ruling race, we see an illustration of the natural tendency of the organic world to grow more perfect; and, in their influence in repressing the advance of others, an example of one of those disturbing causes before enumerated, that *force of external circumstances* which causes such wide chasms in the regular series of animated being.

When the individuals of the dominant race became very numerous, their ideas greatly increased in number, and they felt the necessity of communicating them

to each other, and of augmenting and varying the signs proper for the communication of ideas. Meanwhile the inferior quadrumanous animals, although most of them were gregarious, acquired no new ideas, being persecuted and restless in the deserts, and obliged to fly and conceal themselves, so that they conceived no new wants. Such ideas as they already had remained unaltered, and they could dispense with the communication of the greater part of these. To make themselves, therefore, understood by their fellows, required merely a few movements of the body or limbs — whistling, and the uttering of certain cries varied by the inflexions of the voice.

On the contrary, the individuals of the ascendant race, animated with a desire of interchanging their ideas, which became more and more numerous, were prompted to multiply the means of communication, and were no longer satisfied with mere pantomimic signs, nor even with all the possible inflexions of the voice ; but made continual efforts to acquire the power of uttering articulate sounds, employing a few at first, but afterwards varying and perfecting them according to the increase of their wants. The habitual exercise of their throat, tongue, and lips, insensibly modified the conformation of these organs, until they became fitted for the faculty of speech.*

In effecting this mighty change, “the exigencies of the individuals were the sole agents ; they gave rise to efforts, and the organs proper for articulating sounds were developed by their habitual employment.” Hence, in this peculiar race, the origin of the admirable faculty of speech ; hence also the diversity of languages, since

* Lamarck’s Phil. Zool. tom. i. p. 356.

the distance of places where the individuals composing the race established themselves soon favoured the corruption of conventional signs.*

In conclusion, it may be proper to observe that the above sketch of the Lamarckian theory is no exaggerated picture, and those passages which have probably excited the greatest surprise in the mind of the reader are literal translations from the original.

* Lamarck's Phil. Zool. tom. i. p. 357.

CHAPTER II.

TRANSMUTATION OF SPECIES — *continued.*

Recapitulation of the arguments in favour of the theory of transmutation of species — Their insufficiency — Causes of difficulty in discriminating species — Some varieties possibly more distinct than certain individuals of distinct species — Variability in a species consistent with a belief that the limits of deviation are fixed — No facts of transmutation authenticated — Varieties of the Dog — the Dog and Wolf distinct species — Mummies of various animals from Egypt identical in character with living individuals — Seeds and plants from the Egyptian tombs — Modifications produced in plants by agriculture and gardening.

THE theory of the transmutation of species, considered in the last chapter, has met with some degree of favour from many naturalists, from their desire to dispense, as far as possible, with the repeated intervention of a First Cause, as often as geological monuments attest the successive appearance of new races of animals and plants, and the extinction of those pre-existing. But, independently of a predisposition to account, if possible, for a series of changes in the organic world by the regular action of secondary causes, we have seen that in truth many perplexing difficulties present themselves to one who attempts to establish the nature and reality of the specific character. And if once there appears ground of reasonable doubt, in regard to the

constancy of species, the amount of transformation which they are capable of undergoing may seem to resolve itself into a mere question of the quantity of time assigned to the past duration of animate existence.

Before entering upon the reasons which may be adduced for rejecting Lamarck's hypothesis, I shall recapitulate, in a few words, the phenomena, and the whole train of thought, by which I conceive it to have been suggested, and which have gained for this and analogous theories, both in ancient and modern times, a considerable number of votaries.

In the first place, the various groups into which plants and animals may be thrown seem almost invariably, to a beginner, to be so natural, that he is usually convinced at first, as was Linnæus to the last, "that genera are as much founded in nature as the species which compose them."* When, by examining the numerous intermediate gradations the student finds all lines of demarcation to be in most instances obliterated, even where they at first appeared most distinct, he grows more and more sceptical as to the real existence of genera, and finally regards them as mere arbitrary and artificial signs, invented, like those which serve to distinguish the heavenly constellations, for the convenience of classification, and having as little pretensions to reality.

Doubts are then engendered in his mind as to whether species may not also be equally unreal. The student is probably first struck with the phenomenon, that some individuals are made to deviate widely from the ordinary type by the force of peculiar circum-

* *Genus omne est naturale, in primordio tale creatum, &c.*
Phil. Bot. § 159. See also ibid § 162.

stances, and with the still more extraordinary fact, that the newly acquired peculiarities are faithfully transmitted to the offspring. How far, he asks, may such variations extend in the course of indefinite periods of time, and during great vicissitudes in the physical condition of the globe? His growing incertitude is at first checked by the reflection, that nature has forbidden the intermixture of the descendants of distinct original stocks, or has, at least, entailed sterility on their offspring, thereby preventing their being confounded together; and pointing out that a multitude of distinct types must have been created in the beginning, and must have remained pure and uncorrupted to this day.

Relying on this general law, he endeavours to solve each difficult problem by direct experiment, until he is again astounded by the phenomenon of a prolific hybrid, and still more by an example of a hybrid perpetuating itself throughout several generations in the vegetable world. He then feels himself reduced to the dilemma of choosing between two alternatives; either to reject the test, or to declare that the two species, from the union of which the fruitful progeny has sprung, were mere varieties. If he prefer the latter, he is compelled to question the reality of the distinctness of all other supposed species which differ no more than the parents of such prolific hybrids: for although he may not be enabled immediately to procure, in all such instances, a fruitful offspring; yet experiments show, that after repeated failures, the union of two recognized species may at last, under very favourable circumstances, give birth to a fertile progeny. Such circumstances, therefore, the naturalist

may conceive to have occurred again and again, in the course of a great lapse of ages.

His first opinions are now fairly unsettled, and every stay at which he has caught has given way one after another ; he is in danger of falling into any new and visionary doctrine which may be presented to him ; for he now regards every part of the animate creation as void of stability, and in a state of continual flux. In this mood he encounters the Geologist, who relates to him how there have been endless vicissitudes in the shape and structure of organic beings in former ages — how the approach to the present system of things has been gradual — that there has been a progressive development of organization subservient to the purposes of life, from the most simple to the most complex state — that the appearance of man is the last phenomenon in a long succession of events ; and finally, that a series of physical revolutions can be traced in the inorganic world, coeval and coextensive with those of organic nature.

These views seem immediately to confirm all his preconceived doubts as to the stability of the specific character, and he begins to think there may exist an inseparable connection between a series of changes in the inanimate world, and the capability of the species to be indefinitely modified by the influence of external circumstances. Henceforth his speculations know no definite bounds ; he gives the rein to conjecture, and fancies that the outward form, internal structure, instinctive faculties, nay, that reason itself may have been gradually developed from some of the simplest states of existence — that all animals, that man himself, and the irrational beings, may have had one common origin ; that all may be parts of one continuous and

progressive scheme of development, from the most imperfect to the more complex ; in fine, he renounces his belief in the high genealogy of his species, and looks forward, as if in compensation, to the future perfectibility of man in his physical, intellectual, and moral attributes.

Let us now proceed to consider what is defective in evidence, and what fallacious in reasoning, in the grounds of these strange conclusions. Blumenbach judiciously observes, that "no general rule can be laid down for determining the distinctness of species, as there is no particular class of characters which can serve as a criterion. In each case we must be guided by *analogy* and *probability*." The multitude, in fact, and complexity of the proofs to be weighed, is so great, that we can only hope to obtain presumptive evidence, and we must, therefore, be the more careful to derive our general views as much as possible from those observations where the chances of deception are least. We must be on our guard not to tread in the footsteps of the naturalists of the middle ages, who believed the doctrine of spontaneous generation to be applicable to all those parts of the animal and vegetable kingdoms which they least understood, in direct contradiction to the analogy of all the parts best known to them ; and who, when at length they found that insects and cryptogamous plants were also propagated from eggs or seeds, still persisted in retaining their old prejudices respecting the infusory animalcules and other minute beings, the generation of which had not then been demonstrated by the microscope to be governed by the same laws.

Lamarck has, indeed, attempted to raise an argument in favour of his system, out of the very confusion

which has arisen in the study of some orders of animals and plants, in consequence of the slight shades of difference which separate the new species discovered within the last half century. That the embarrassment of those who attempt to classify and distinguish the new acquisitions, poured in such multitudes into our museums, should increase with the augmentation of their number, is quite natural ; since to obviate this it is not enough that our powers of discrimination should keep pace with the increase of the objects, but we ought to possess greater opportunities of studying each animal and plant in all stages of its growth, and to know profoundly their history, their habits, and physiological characters, throughout several generations ; for, in proportion as the series of known animals grows more complete, none can doubt that there is a nearer approximation to a graduated scale of being ; and thus the most closely allied species will be found to possess a greater number of characters in common.

Causes of the difficulty of discriminating species. — But, in point of fact, our new acquisitions consist, more and more as we advance, of specimens brought from foreign and often very distant and barbarous countries. A large proportion have never even been seen alive by scientific inquirers. Instead of having specimens of the young, the adult, and the aged individuals of each sex, and possessing means of investigating the anatomical structure, the peculiar habits, and instincts of each, what is usually the state of our information ? A single specimen, perhaps, of a dried plant, or a stuffed bird or quadruped ; a shell, without the soft parts of the animal ; an insect in one stage of its numerous transformations ; — these are the scanty and imperfect data which the naturalist possesses.

Such information may enable us to separate species which stand at a considerable distance from each other; but we have no right to expect any thing but difficulty and ambiguity, if we attempt, from such imperfect opportunities, to obtain distinctive marks for defining the characters of species which are closely related.

If Lamarck could introduce so much certainty and precision into the classification of several thousand species of recent and fossil shells, notwithstanding the extreme remoteness of the organization of these animals from the type of those vertebrated species which are best known, and in the absence of so many of the living inhabitants of shells, we are led to form an exalted conception of the degree of exactness to which specific distinctions are capable of being carried, rather than to call in question their reality.

When our data are so defective, the most acute naturalist must expect to be sometimes at fault, and, like the novice, to overlook essential points of difference, passing unconsciously from one species to another, until, like one who is borne along in a current, he is astonished, on looking back, at observing that he has reached a point so remote from that whence he set out.

It is by no means improbable, that, when the series of species of certain genera is very full, they may be found to differ less widely from each other than do the mere varieties or races of certain species. If such a fact could be established, it would, undoubtedly, diminish the chance of our obtaining certainty in our results; but it would by no means overthrow our confidence in the reality of species.

Some mere varieties possibly more distinct than certain individuals of distinct species. — It is almost necessary,

indeed, to suppose that varieties will differ in some cases more decidedly than some species, if we admit that there is a graduated scale of being, and assume that the following laws prevail in the economy of the animate creation :—first, that the organization of individuals is capable of being modified to a limited extent by the force of external causes ; secondly, that these modifications are, to a certain extent, transmissible to their offspring ; thirdly, that there are fixed limits, beyond which the descendants from common parents can never deviate from a certain type ; fourthly, that each species springs from one original stock, and can never be permanently confounded by intermixing with the progeny of any other stock ; fifthly, that each species shall endure for a considerable period of time. Now, let us assume, for the present, these rules hypothetically, and see what consequences may naturally be expected to result from them.

We must suppose that when the Author of Nature creates an animal or plant, all the possible circumstances in which its descendants are destined to live are foreseen, and that an organization is conferred upon it which will enable the species to perpetuate itself and survive under all the varying circumstances to which it must be inevitably exposed. Now, the range of variation of circumstances will differ essentially in almost every case. Let us take, for example, any one of the most influential conditions of existence, such as temperature. In some extensive districts near the equator, the thermometer might never vary, throughout several thousand centuries, for more than 20° Fahrenheit ; so that if a plant or animal be provided with an organization fitting it to endure such a range, it may continue on the globe for that immense

period, although every individual might be liable at once to be cut off by the least possible excess of heat or cold beyond the determinate degree. But if a species be placed in one of the temperate zones, and have a constitution conferred on it capable of supporting a similar range of temperature only, it will inevitably perish before a single year has passed away.

Humboldt has shown that, at Cumana, within the tropics, there is a difference of only four degrees (Fahr.) between the temperature of the warmest and coldest months; whereas, in the temperate zones, the annual variation amounts to about 60°, and the extreme range of the thermometer in Canada is not less than 90°.

The same remark might be applied to any other condition, as food, for example: it may be foreseen that the supply will be regular throughout indefinite periods in one part of the world, and in another very precarious and fluctuating both in kind and quantity. Different qualifications may be required for enabling species to live for a considerable time under circumstances so changeable. If, then, temperature and food be among those external causes which, according to certain laws of animal and vegetable physiology, modify the organization, form, or faculties, of individuals, we instantly perceive that the degrees of variability from a common standard must differ widely in the two cases above supposed; since there is a necessity of accommodating a species in one case to a much greater latitude of circumstances than in the other.

If it be a law, for instance, that scanty sustenance should check those individuals in their growth which are enabled to accommodate themselves to privations of this kind, and that a parent, prevented in this

manner from attaining the size proper to its species, should produce a dwarfish offspring, a stunted race will arise, as is remarkably exemplified in some varieties of the horse and dog. The difference of stature in some races of dogs, when compared to others, is as one to five in linear dimensions, making a difference of a hundred-fold in volume.* Now, there is good reason to believe that species in general are by no means susceptible of existing under a diversity of circumstances, which may give rise to such a disparity in size, and, consequently, there will be a multitude of distinct species, of which no two adult individuals can ever depart so widely from a certain standard of dimensions as the mere varieties of certain other species — the dog, for instance. Now, we have only to suppose that what is true of size, may also hold in regard to colour and many other attributes ; and it will at once follow, that the degree of possible discordance between varieties of the same species may, in certain cases, exceed the utmost disparity which can arise between two individuals of many distinct species.

The same remarks may hold true in regard to instincts ; for, if it be foreseen that one species will have to encounter a great variety of foes, it may be necessary to arm it with great cunning and circumspection, or with courage or other qualities capable of developing themselves on certain occasions ; such, for example as those migratory instincts which are so remarkably exhibited at particular periods, after they have remained dormant for many generations. The history and habits of one variety of such a species may often differ more considerably from some other than

* Cuvier, Disc. Prélim. p. 128. sixth edition.

those of many distinct species which have no such latitude of accommodation to circumstances.

Extent of known variability in species. — Lamarck has somewhat misstated the idea commonly entertained of a species; for it is not true that naturalists in general assume that the organization of an animal or plant remains absolutely constant, and that it can never vary in any of its parts.* All must be aware that circumstances influence the habits, and that the habits may alter the state of the parts and organs; but the difference of opinion relates to the extent to which these modifications of the habits and organs of a particular species may be carried.

Now, let us first inquire what positive facts can be adduced in the history of known species, to establish a great and permanent amount of change in the form, structure, or instinct of individuals descending from some common stock. The best authenticated examples of the extent to which species can be made to vary may be looked for in the history of domesticated animals and cultivated plants. It usually happens, that those species, both of the animal and vegetable kingdom, which have the greatest pliability of organization, those which are most capable of accommodating themselves to a great variety of new circumstances, are most serviceable to man. These only can be carried by him into different climates, and can have their properties or instincts variously diversified by differences of nourishment and habits. If the resources of a species be so limited, and its habits and faculties be of such a confined and local character, that it can only flourish in a few particular spots, it can rarely be of great utility.

* Phil. Zool. tom. i. p. 266.

We may consider, therefore, that, in the domestication of animals and the cultivation of plants, mankind have first selected those species which have the most flexible frames and constitutions, and have then been engaged for ages in conducting a series of experiments, with much patience and at great cost, to ascertain what may be the greatest possible deviation from a common type which can be elicited in these extreme cases.

Varieties of the dog — no transmutation.—The modifications produced in the different races of dogs exhibit the influence of man in the most striking point of view. These animals have been transported into every climate, and placed in every variety of circumstances ; they have been made, as a modern naturalist observes, the servant, the companion, the guardian, and the intimate friend of man, and the power of a superior genius has had a wonderful influence, not only on their forms, but on their manners and intelligence.* Different races have undergone remarkable changes in the quantity and colour of their clothing ; the dogs of Guinea are almost naked, while those of the arctic circle are covered with a warm coat both of hair and wool, which enables them to bear the most intense cold without inconvenience. There are differences also of another kind no less remarkable, as in size, the length of their muzzles, and the convexity of their foreheads.

But, if we look for some of those essential changes which would be required to lend even the semblance of a foundation for the theory of Lamarck, respecting the growth of new organs and the gradual obliteration

* Dureau de la Malle, Ann. des Sci. Nat. tom. xxi. p. 63.
Sept. 1830.

of others, we find nothing of the kind. For, in all these varieties of the dog, says Cuvier, the relation of the bones with each other remains essentially the same; the form of the teeth never changes in any perceptible degree, except that, in some individuals, one additional false grinder occasionally appears, sometimes on the one side, and sometimes on the other.* The greatest departure from a common type—and it constitutes the maximum of variation as yet known in the animal kingdom—is exemplified in those races of dogs which have a supernumerary toe on the hind foot with the corresponding tarsal bones; a variety analogous to one presented by six-fingered families of the human race.†

Lamarck has thrown out as a conjecture, that the wolf may have been the original of the dog; and eminent naturalists are still divided in opinion on this subject. It seems now admitted that both species agree in the period of gestation, and Mr. Owen has been unable to confirm the alleged difference in the structure of a part of the intestinal canal.‡ Mr. Bell inclines to the opinion that all the various races of dogs have descended from one common stock, of which the wolf is the original source.§

It is well known that the horse, the ox, the boar, and other domestic animals, which have been introduced into South America, and have run wild in many parts, have entirely lost all marks of domesticity, and have reverted to the original characters of their species. But dogs have also become wild in Cuba,

* Disc. Prél. p. 129. sixth edition.

† Ibid.

‡ Güldenstädt, cited by Prichard, Phys. Hist. of Mankind, vol. i. p. 96.

§ History of British Quadrupeds, p. 200. 1837.

Hayti, and in all the Caribbean islands. In the course of the seventeenth century, they hunted in packs from twelve to fifty, or more, in number, and fearlessly attacked herds of wild boars and other animals. It is natural, therefore, to inquire to what form they reverted? Now, they are said by many travellers to have resembled very nearly the shepherd's dog; but it is certain that they were never turned into wolves. They were extremely savage, and their ravages appear to have been as much dreaded as those of wolves; but when any of their whelps were caught, and brought from the woods to the towns, they grew up in the most perfect submission to man.

Many examples might be adduced to prove that the extent to which the alteration of species can be pushed in the domestic state depends on the original capacity of the species to admit of variation. The horse has been as long domesticated as the dog, yet its different races depart much less widely from a common type; the ass has been still less changed, the camel scarcely at all, yet these species have probably been subjected to the influence of domestication as long as the horse.

Mummies of animals in Egyptian tombs identical with species still living. — As the advocates of the theory of transmutation trust much to the slow and insensible changes which time may work, they are accustomed to lament the absence of accurate descriptions, and figures of particular animals and plants, handed down from the earliest periods of history, such as might have afforded data for comparing the condition of species, at two periods considerably remote. But, fortunately, we are in some measure independent of such evidence: for, by a singular accident, the priests of Egypt have bequeathed to us, in their cemeteries,

that information which the museums and works of the Greek philosophers have failed to transmit.

For the careful investigation of these documents, we are greatly indebted to the skill and diligence of those naturalists who accompanied the French armies during their brief occupation of Egypt : that conquest of four years, from which we may date the improvement of the modern Egyptians in the arts and sciences, and the rapid progress which has been made of late in our knowledge of the arts and sciences of their remote predecessors. Instead of wasting their whole time, as so many preceding travellers had done, in exclusively collecting human mummies, M. Geoffroy and his associates examined diligently, and sent home great numbers of embalmed bodies of consecrated animals, such as the bull, the dog, the cat, the ape, the ichneumon, the crocodile, and the ibis.

To those who have never been accustomed to connect the facts of Natural History with philosophical speculations, who have never raised their conceptions of the end and import of such studies beyond the mere admiration of isolated and beautiful objects, or the exertion of skill in detecting specific differences, it will seem incredible that amidst the din of arms, and the stirring excitement of political movements, so much enthusiasm could have been felt in regard to these precious remains.

In the official report, drawn up by the Professors of the Museum at Paris, on the value of these objects, there are some eloquent passages, which may appear extravagant, unless we reflect how fully these naturalists could appreciate the bearing of the facts thus brought to light on the past history of the globe.

“It seems,” say they, “as if the superstition of the

ancient Egyptians had been inspired by Nature, with a view of transmitting to after ages a monument of her history. That extraordinary and whimsical people, by embalming with so much care the brutes which were the objects of their stupid adoration, have left us, in their sacred grottos, cabinets of zoology almost complete. The climate has conspired with the art of embalming to preserve the bodies from corruption, and we can now assure ourselves by our own eyes what was the state of a great number of species three thousand years ago. We can scarcely restrain the transports of our imagination, on beholding thus preserved, with their minutest bones, with the smallest portions of their skin, and in every particular most perfectly recognizable, many an animal, which at Thebes or Memphis, two or three thousand years ago, had its own priests and altars." *

Among the Egyptian mummies thus procured were not only those of numerous wild quadrupeds, birds, and reptiles; but, what was perhaps of still higher importance in deciding the great question under discussion, there were the mummies of domestic animals, among which those above mentioned, the bull, the dog, and the cat, were frequent. Now, such was the conformity of the whole of these species to those now living, that there was no more difference, says Cuvier, between them than between the human mummies and the embalmed bodies of men of the present day. Yet some of these animals have since that period been transported by man to almost every climate, and forced to accommodate their habits to the greatest variety of circumstances. The cat, for example, has been carried

* Ann. du Muséum d'Hist. Nat. tom. i. p. 284. 1802. The reporters were M M. Cuvier, Lacépède, and Lamarck.

over the whole earth, and, within the last three centuries, has been naturalized in every part of the new world, — from the cold regions of Canada to the tropical plains of Guiana ; yet it has scarcely undergone any perceptible mutation, and is still the same animal which was held sacred by the Egyptians.

Of the ox, undoubtedly, there are many very distinct races : but the bull Apis, which was led in solemn processions by the Egyptian priests, did not differ from some of those now living. The black cattle that have run wild in America, where there were many peculiarities in the climate not to be found, perhaps, in any part of the old world, and where scarcely a single plant on which they fed was of precisely the same species, instead of altering their form and habits, have actually reverted to the exact likeness of the aboriginal wild cattle of Europe.

In answer to the arguments drawn from the Egyptian mummies, Lamarck said that they were identical with their living descendants in the same country, because the climate and physical geography of the banks of the Nile have remained unaltered for the last thirty centuries. But why, it may be asked, have other individuals of these species retained the same characters in so many different quarters of the globe, where the climate and many other conditions are so varied ?

Seeds and plants from the Egyptian tombs.— The evidence derived from the Egyptian monuments was not confined to the animal kingdom ; the fruits, seeds, and other portions of twenty different plants, were faithfully preserved in the same manner ; and among these the common wheat was procured by Delille, from closed vessels in the sepulchres of the kings, the grains of which retained not only their form, but even

their colour; so effectual has proved the process of embalming with bitumen in a dry and equable climate. No difference could be detected between this wheat and that which now grows in the East and elsewhere, and similar identifications were made in regard to all the other plants.

Native country of the common wheat. — And here I may observe, that there is an obvious answer to Lamarck's objection, that the botanist cannot point out a country where the common wheat grows wild, unless in places where it may have been derived from neighbouring cultivation.* All naturalists are well aware that the geographical distribution of a great number of species is extremely limited; that it was to be expected that every useful plant should first be cultivated successfully in the country where it was indigenous; and that, probably, every station which it partially occupied, when growing wild, would be selected by the agriculturist as best suited to it when artificially increased. Palestine has been conjectured, by a late writer on the Cerealia, to have been the original habitation of wheat and barley; a supposition which appears confirmed by Hebrew and Egyptian traditions, and by tracing the migrations of the worship of Ceres, as indicative of the migrations of the plant.†

If we are to infer that some one of the wild grasses has been transformed into the common wheat, and that some animal of the genus *canis*, still unreclaimed, has been metamorphosed into the dog, merely because we cannot find the domestic dog, or the cultivated wheat, in a state of nature, we may be next called upon to

* Phil. Zool. tom. i. p. 227.

† L'Origine et la Patrie des Céréales, &c., Ann. des Sci. Nat. tom. ix. p. 61.

make similar admissions in regard to the camel ; for it seems very doubtful whether any race of this species of quadruped is now wild.

Changes in plants produced by cultivation. — But if agriculture, it will be said, does not supply examples of extraordinary changes of form and organization, the horticulturist can, at least, appeal to facts which may confound the preceding train of reasoning. The crab has been transformed into the apple ; the sloe into the plum : flowers have changed their colour, and become double ; and these new characters can be perpetuated by seed : a bitter plant, with wavy sea-green leaves, has been taken from the sea-side, where it grew like wild charlock ; has been transplanted into the garden, lost its saltiness, and has been metamorphosed into two distinct vegetables, as unlike each other as is each to the parent plant — the red cabbage and the cauliflower. These, and a multitude of analogous facts, are undoubtedly among the wonders of nature, and attest more strongly, perhaps, the extent to which species may be modified, than any examples derived from the animal kingdom. But in these cases we find that we soon reach certain limits, beyond which we are unable to cause the individuals descending from the same stock to vary ; while, on the other hand, it is easy to show that these extraordinary varieties could seldom arise, and could never be perpetuated in a wild state for many generations, under any imaginable combination of accidents. They may be regarded as extreme cases, brought about by human interference, and not as phenomena which indicate a capability of indefinite modification in the natural world.

The propagation of a plant by buds or grafts, and by cuttings, is obviously a mode which nature does

not employ; and this multiplication, as well as that produced by roots and layers, seems merely to operate as an extension of the life of an individual, and not as a reproduction of the species such as happens by seed. All plants increased by grafts or layers retain precisely the peculiar qualities of the individual to which they owe their origin, and, like an individual, they have only a determinate existence; in some cases longer, and in others shorter.* It seems now admitted by horticulturists, that none of our garden varieties of fruit are entitled to be considered strictly permanent, but that they wear out after a time †; and we are thus compelled to resort again to seeds: in which case there is so decided a tendency in the seedlings to revert to the original type, that our utmost skill is sometimes baffled in attempting to recover the desired variety.

Varieties of the cabbage. — The different races of cabbages afford, as was admitted, an astonishing example of deviation from a common type; but we can scarcely conceive them to have originated, much less to have lasted for several generations, without the intervention of man. It is only by strong manures that these varieties have been obtained, and in poorer soils they instantly degenerate. If, therefore, we suppose in a state of nature the seed of the wild *Brassica oleracea* to have been wafted from the sea-side to some spot enriched by the dung of animals, and to have there become a cauliflower, it would soon diffuse its seed to some comparatively sterile soils around, and the offspring would relapse to the likeness of the parent stock.

* Smith's Introduction to Botany, p. 138. Edit. 1807.

† See Mr. Knight's Observations, Hort. Trans. vol. ii. p. 160.

But if we go so far as to imagine the soil, in the spot first occupied, to be constantly manured by herds of wild animals, so as to continue as rich as that of a garden, still the variety could not be maintained; because we know that each of these races is prone to fecundate others, and gardeners are compelled to exert the utmost diligence to prevent cross-breeds. The intermixture of the pollen of varieties growing in the poorer soil around would soon destroy the peculiar characters of the race which occupied the highly manured tract; for, if these accidents so continually happen, in spite of our care, among the culinary varieties, it is easy to see how soon this cause might obliterate every marked singularity in a wild state.

Besides, it is well known that, although the pampered races which we rear in our gardens for use or ornament may often be perpetuated by seed, yet they rarely produce seed in such abundance, or so prolific in quality, as wild individuals; so that if the care of man were withdrawn, the most fertile variety would always, in the end, prevail over the more sterile.

Similar remarks may be applied to the double flowers, which present such strange anomalies to the botanist. The ovary, in such cases, is frequently abortive; and the seeds, when prolific, are generally much fewer than where the flowers are single.

Changes caused by soil.—Some curious experiments, recently made on the production of blue instead of red flowers in the *Hydrangea hortensis*, illustrate the immediate effect of certain soils on the colours of the calyx and petals. In garden-mould or compost, the flowers are invariably red; in some kinds of bog-earth they are blue; and the same change is always produced by a particular sort of yellow loam.

Varieties of the primrose.—Linnæus was of opinion that the primrose, oxlip, cowslip, and polyanthus, were only varieties of the same species. The majority of modern botanists, on the contrary, consider them to be distinct, although some conceived that the oxlip might be a cross between the cowslip and the primrose. Mr. Herbert has lately recorded the following experiment:—“I raised from the natural seed of one umbel of a highly manured red cowslip a primrose, a cowslip, oxslips of the usual and other colours, a black polyanthus, a hose-in-hose cowslip, and a natural primrose bearing its flower on a polyanthus stalk. From the seed of that very hose-in-hose cowslip, I have since raised a hose-in-hose primrose. I therefore consider all these to be only local varieties, depending upon soil and situation.”* Professor Henslow, of Cambridge, has since confirmed this experiment of Mr. Herbert; so that we have an example, not only of the remarkable varieties which the florist can obtain from a common stock, but of the distinctness of analogous races found in a wild state.†

On what particular ingredient, or quality in the earth, these changes depend, has not yet been ascertained.‡ But gardeners are well aware that particular plants, when placed under the influence of certain circumstances, are changed in various ways, according to the species; and as often as the experiments are repeated, similar results are obtained. The nature of these results, however, depends upon the species, and they are, therefore, part of the specific character; they exhibit the same phenomena again and again, and

* Hort. Trans. vol. iv. p. 19.

† Loudon's Mag. of Nat. Hist. Sept. 1830, vol. iii. p. 408.

‡ Hort. Trans. vol. iii. p. 173.

indicate certain fixed and invariable relations between the physiological peculiarities of the plant, and the influence of certain external agents. They afford no ground for questioning the instability of species, but rather the contrary: they present us with a class of phenomena which, when they are more thoroughly understood, may afford some of the best tests for identifying species, and proving that the attributes originally conferred endure so long as any issue of the original stock remains upon the earth.

CHAPTER III.

WHETHER SPECIES HAVE A REAL EXISTENCE IN NATURE — *continued.*

Limits of the variability of species — Species susceptible of modification may be altered greatly in a short time, and in a few generations ; after which they remain stationary — The animals now subject to man had originally an aptitude to domesticity — Acquired peculiarities which become hereditary have a close connexion with the habits or instincts of the species in a wild state — Some qualities in certain animals have been conferred with a view of their relation to man — Wild elephant domesticated in a few years, but its faculties incapable of further development.

Variability of a species compared to that of an individual. — I ENDEAVoured, in the last chapter, to show, that a belief in the reality of species is not inconsistent with the idea of a considerable degree of variability in the specific character. This opinion, indeed, is little more than an extension of the idea which we must entertain of the identity of an individual, throughout the changes which it is capable of undergoing.

If a quadruped, inhabiting a cold northern latitude, and covered with a warm coat of hair or wool, be transported to a southern climate, it will often in the course of a few years, shed a considerable portion of its coat, which it gradually recovers on being again

restored to its native country. Even there the same changes are, perhaps, superinduced to a certain extent by the return of winter and summer. We know that the Alpine hare (*Lepus variabilis*, Pal.) and the ermine, or stoat (*Mustela erminea*, Linn.) become white during winter, and again obtain their full colour during the warmer season; that the plumage of the ptarmigan undergoes a like metamorphosis in colour and quantity, and that the change is equally temporary. We are aware that, if we reclaim some wild animal, and modify its habits and instincts by domestication, it may, if it escapes, become in a few years nearly as wild and untractable as ever; and if the same individual be again retaken, it may be reduced to its former tame state. A plant is placed in a prepared soil, in order that the petals of its flowers may multiply, and their colour be heightened or changed; if we then withhold our care, the flowers of this same individual become again single. In these, and innumerable other instances, we must suppose that the individual was produced with a certain number of qualities; and, in the case of animals, with a variety of instincts, some of which may or may not be developed according to circumstances, or which, after having been called forth, may again become latent when the exciting causes are removed.

Now, the formation of races seems the necessary consequence of such a capability in individuals to vary, if it be a general law that the offspring should very closely resemble the parent. But, before we can infer that there are no limits to the deviation from an original type which may be brought about in the course of an indefinite number of generations, we ought to have some proof that, in each successive generation,

individuals may go on acquiring an equal amount of new peculiarities, under the influence of equal changes of circumstances. The balance of evidence, however, inclines most decidedly on the opposite side; for in all cases we find that the quantity of divergence diminishes from the first in a very rapid ratio.

Species susceptible of modification may be greatly altered in a few generations. — It cannot be objected, that it is out of our power to go on varying the circumstances in the same manner as might happen in the natural course of events during some great geological cycle. For in the first place, where a capacity is given to individuals to adapt themselves to new circumstances, it does not generally require a very long period for its development; if, indeed, such were the case, it is not easy to see how the modification would answer the ends proposed, for all the individuals would die before new qualities, habits, or instincts were conferred.

When we have succeeded in naturalizing some tropical plant in a temperate climate, nothing prevents us from attempting gradually to extend its distribution to higher latitudes, or to greater elevations above the level of the sea, allowing equal quantities of time, or an equal number of generations, for habituating the species to successive increments of cold. But every husbandman and gardener is aware that such experiments will fail; and we are more likely to succeed in making some plants, in the course of the first two generations, support a considerable degree of difference of temperature than a very small difference afterwards, though we persevere for many centuries.

It is the same if we take any other cause instead of temperature; such as the quality of the food, or the

kind of dangers to which an animal is exposed, or the soil in which a plant lives. The alteration in habits, form, or organization, is often rapid during a short period; but when the circumstances are made to vary further, though in ever so slight a degree, all modification ceases, and the individual perishes. Thus some herbivorous quadrupeds may be made to feed partially on fish or flesh; but even these can never be taught to live on some herbs which they reject, and which would even poison them, although the same may be very nutritious to other species of the same natural order. So, when man uses force or stratagem against wild animals, the persecuted race soon becomes more cautious, watchful, and cunning; new instincts seem often to be developed, and to become hereditary in the first two or three generations: but let the skill and address of man increase, however gradually, no further variation can take place, no new qualities are elicited by the increasing dangers. The alteration of the habits of the species has reached a point beyond which no ulterior modification is possible, however indefinite the lapse of ages during which the new circumstances operate. Extirpation then follows, rather than such a transformation as could alone enable the species to perpetuate itself under the new state of things.

Animals now subject to man had originally an aptitude to domesticity.—It has been well observed by M. F. Cuvier and M. Dureau de la Malle, that, unless some animals had manifested in a wild state an aptitude to second the efforts of man, their domestication would never have been attempted. If they had all resembled the wolf, the fox, and the hyæna, the patience of the experimentalist would have been exhausted by innumerable failures before he at last succeeded in obtain-

ing some imperfect results; so, if the first advantages derived from the cultivation of plants had been elicited by as tedious and costly a process as that by which we now make some slight additional improvement in certain races, we should have remained to this day in ignorance of the greater number of their useful qualities.

Acquired instincts of some animals become hereditary. — It is undoubtedly true, that many new habits and qualities have not only been acquired in recent times by certain races of dogs, but have been transmitted to their offspring. But in these cases it will be observed, that the new peculiarities have an intimate relation to the habits of the animal in a wild state, and therefore do not attest any tendency to departure to an indefinite extent from the original type of the species. A race of dogs employed for hunting deer in the platform of Santa Fé, in Mexico, affords a beautiful illustration of a new hereditary instinct. The mode of attack, observes M. Roulin, which they employ, consists in seizing the animal by the belly and overturning it by a sudden effort, taking advantage of the moment when the body of the deer rests only upon the fore-legs. The weight of the animal thus thrown over is often six times that of its antagonist. The dog of pure breed inherits a disposition to this kind of chase, and never attacks a deer from before while running. Even should the deer, not perceiving him, come directly upon him, the dog steps aside and makes his assault on the flank; whereas other hunting dogs, though of superior strength, and general sagacity, which are brought from Europe, are destitute of this instinct. For want of similar precautions, they are often killed by the deer on the spot, the vertebræ

of their neck being dislocated by the violence of the shock.*

A new instinct has also become hereditary in a mongrel race of dogs employed by the inhabitants of the banks of the Magdalena almost exclusively in hunting the white-lipped pecari. The address of these dogs consists in restraining their ardour, and attaching themselves to no animal in particular, but keeping the whole herd in check. Now, among these dogs some are found, which, the very first time they are taken to the woods, are acquainted with this mode of attack; whereas, a dog of another breed starts forward at once, is surrounded by the pecari, and, whatever may be his strength, is destroyed in a moment.

Some of our countrymen, engaged of late in conducting one of the principal mining associations in Mexico, that of Real del Monte, carried out with them some English greyhounds of the best breed, to hunt the hares which abound in that country. The great platform which is the scene of sport is at an elevation of about nine thousand feet above the level of the sea, and the mercury in the barometer stands habitually at the height of about nineteen inches. It was found that the greyhounds could not support the fatigues of a long chase in this attenuated atmosphere, and before they could come up with their prey, they lay down gasping for breath; but these same animals have produced whelps which have grown up, and are not in the least degree incommoded by the want of density in the air, but run down the hares with as much ease as the fleetest of their race in this country.

* M. Roulin, Ann. des Sci. Nat. tom. xvi. p. 16. 1829.

The fixed and deliberate stand of the pointer has with propriety been regarded as a mere modification of a habit, which may have been useful to a wild race accustomed to wind game, and steal upon it by surprise, first pausing for an instant, in order to spring with unerring aim. The faculty of the Retriever, however, may justly be regarded as more inexplicable and less easily referrible to the instinctive passions of the species. M. Majendie, says a French writer in a recently published memoir, having learnt that there was a race of dogs in England which stopped and brought back game of their own accord, procured a pair, and, having obtained a whelp from them, kept it constantly under his eyes, until he had an opportunity of assuring himself that, without having received any instruction, and on the very first day that it was carried to the chase, it brought back game with as much steadiness as dogs which had been schooled into the same manœuvre by means of the whip and collar.

Attributes of animals in their relation to man.—Such attainments, as well as the habits and dispositions which the shepherd's dog and many others inherit, seem to be of a nature and extent which we can hardly explain by supposing them to be modifications of instincts necessary for the preservation of the species in a wild state. When such remarkable habits appear in races of this species, we may reasonably conjecture that they were given with no other view than for the use of man and the preservation of the dog, which thus obtains protection.

As a general rule, I fully agree with M. F. Cuvier, that, in studying the habits of animals, we must attempt, as far as possible, to refer their domestic qualities to modifications of instincts which are implanted

in them in a state of nature; and that writer has successfully pointed out, in an admirable essay on the domestication of the mammalia, the true origin of many dispositions which are vulgarly attributed to the influence of education alone.* But we should go too far if we did not admit that some of the qualities of particular animals and plants may have been given solely with a view to the connexion which it was foreseen would exist between them and man — especially when we see that connexion to be in many cases so intimate, that the greater number, and sometimes, as in the case of the camel, all the individuals of the species which exist on the earth are in subjection to the human race.

We can perceive in a multitude of animals, especially in some of the parasitic tribes, that certain instincts and organs are conferred for the purpose of defence or attack against some other species. Now, if we are reluctant to suppose the existence of similar relations between man and the instincts of many of the inferior animals, we adopt an hypothesis no less violent, though in the opposite extreme to that which has led some to imagine the whole animate and inanimate creation to have been made solely for the support, gratification, and instruction of mankind.

Many species, most hostile to our persons or property, multiply, in spite of our efforts to repress them; others, on the contrary, are intentionally augmented many hundred fold in number by our exertions. In such instances, we must imagine the relative resources of man and of species, friendly or inimical to him, to have been prospectively calculated and adjusted.. To

* Mém. du Mus. d'Hist. Nat. — Jameson, Ed. New Phil. Journ., Nos. 6, 7, 8.

withhold assent to this supposition, would be to refuse what we must grant in respect to the economy of Nature in every other part of the organic creation; for the various species of contemporary plants and animals have obviously their relative forces nicely balanced, and their respective tastes, passions, and instincts so contrived, that they are all in perfect harmony with each other. In no other manner could it happen that each species, surrounded, as it is, by countless dangers, should be enabled to maintain its ground for periods of considerable duration.

The docility of the individuals of some of our domestic species, extending, as it does, to attainments foreign to their natural habits and faculties, may, perhaps, have been conferred with a view to their association with man. But, lest species should be thereby made to vary indefinitely, we find that such habits are never transmissible by generation.

A pig has been trained to hunt and point game with great activity and steadiness *; and other learned individuals, of the same species, have been taught to spell; but such fortuitous acquirements never become hereditary, for they have no relation whatever to the exigencies of the animal in a wild state, and cannot, therefore, be developments of any instinctive propensities.

Influence of domestication. — An animal in domesticity, says M. F. Cuvier, is not essentially in a different situation, in regard to the feeling of restraint, from one left to itself. It lives in society without constraint, because, without doubt, it was a social animal; and it

* In the New Forest, near Ringwood, Hants, by Mr. Toomer, keeper of Broomy Lodge. I have conversed with witnesses of the fact.

conforms itself to the will of man, because it had a chief, to which, in a wild state, it would have yielded obedience. There is nothing in its new situation that is not conformable to its propensities ; it is satisfying its wants by submission to a master, and makes no sacrifice of its natural inclinations. All the social animals, when left to themselves, form herds more or less numerous ; and all the individuals of the same herd know each other, are mutually attached, and will not allow a strange individual to join them. In a wild state, moreover, they obey some individual, which, by its superiority, has become the chief of the herd. Our domestic species had, originally, this sociability of disposition ; and no solitary species, however easy it may be *to tame it*, has yet afforded true domestic races. We merely, therefore, develope, to our own advantage, propensities which propel the individuals of certain species to draw near to their fellows.

The sheep which we have reared is induced to follow us, as it would be led to follow the flock among which it was brought up ; and, when individuals of gregarious species have been accustomed to one master, it is he alone whom they acknowledge as their chief — he only whom they obey. “ The elephant allows himself to be directed only by the carnaç whom he has adopted ; the dog itself, reared in solitude with its master, manifests a hostile disposition towards all others ; and every body knows how dangerous it is to be in the midst of a herd of cows, in pasturages that are little frequented, when they have not at their head the keeper who takes care of them.

“ Every thing, therefore, tends to convince us, that formerly men were only, with regard to the domestic animals, what those who are particularly charged with

the care of them still are — namely, members of the society which these animals form among themselves ; and that they are only distinguished, in the general mass by the authority which they have been enabled to assume from their superiority of intellect. Thus, every social animal which recognizes man as a member, and as the chief of its herd, is a domestic animal. It might even be said, that, from the moment when such an animal admits man as a member of its society, it is domesticated, as man could not enter into such a society without becoming the chief of it.” *

But the ingenious author whose observations I have here cited, admits that the obedience which the individuals of many domestic species yield indifferently to every person, is without analogy in any state of things which could exist previously to their subjugation by man. Each troop of wild horses, it is true, has some stallion for its chief, who draws after him all the individuals of which the herd is composed ; but, when a domesticated horse has passed from hand to hand, and has served several masters, he becomes equally docile towards *any person*, and is subjected to the whole human race. It seems fair to presume that the capability in the instinct of the horse to be thus modified, was given to enable the species to render greater services to man ; and, perhaps, the facility with which many other acquired characters become hereditary in various races of the horse, may be explicable only on a like supposition. The amble, for example, a pace to which the domestic races in some parts of Spanish America are exclusively trained, has, in the course of several generations, become hereditary, and

* Mém. du Mus. d'Hist. Nat.

is assumed by all the young colts before they are broken in.*

It seems, also, reasonable to conclude, that the power bestowed on the horse, the dog, the ox, the sheep, the cat, and many species of domestic fowls, of supporting almost every climate, was given expressly to enable them to follow man throughout all parts of the globe, in order that we might obtain their services, and they our protection. If it be objected that the elephant, which by the union of strength, intelligence, and docility, can render the greatest services to mankind, is incapable of living in any but the warmest latitudes, we may observe, that the quantity of vegetable food required by this quadruped would render its maintenance in the temperate zone too costly, and in the arctic impossible.

Among the changes superinduced by man, none appear, at first sight, more remarkable than the perfect tameness of certain domestic races. It is well known that, at however early an age we obtain possession of the young of many unreclaimed races, they will retain, throughout life, a considerable timidity and apprehensiveness of danger; whereas, after one or two generations, the descendants of the same stock will habitually place the most implicit confidence in man. There is good reason, however, to suspect that such changes are not without analogy in a state of nature; or, to speak more correctly, in situations where man has not interfered.

We learn from Mr. Darwin, that in the Galapagos archipelago, placed directly under the equator, and nearly 600 miles west of the American continent, that

* Dureau de la Malle, Ann. des Sci. Nat. tom. xxi. p. 58.

all the terrestrial birds, as the finches, doves, hawks, and others, are so tame, that they may be killed with a switch. One day, says this author, "a mocking-bird alighted on the edge of a pitcher which I held in my hand, and began quietly to sip the water, and allowed me to lift it with the vessel from the ground." Yet formerly, when the first Europeans landed, and found no inhabitants in these islands, the birds were even tamer than now; already they are beginning to acquire that salutary dread of man which in countries long settled is natural even to young birds, which have never received any injury. So in the Falkland Islands, both the birds and foxes are entirely without fear of man; whereas, in the adjoining mainland of South America, many of the same species of birds are extremely wild; for there they have for ages been persecuted by the natives.*

Dr. Richardson informs us, in his able history of the habits of the North American animals, that, "in the retired parts of the mountains, where the hunters had seldom penetrated, there is no difficulty in approaching the Rocky Mountain sheep, which there exhibit *the simplicity of character so remarkable in the domestic species*; but where they have been often fired at, they are exceedingly wild, alarm their companions, on the approach of danger, by a hissing noise, and scale the rocks with a speed and agility that baffle pursuit."†

It is probable, therefore, that as man, in diffusing himself over the globe, has tamed many wild races, so, also, he has made many tame races wild. Had some of the larger carnivorous beasts, capable of scaling the

* Darwin's Journ. in Voyage of H. M. S. Beagle, p. 475.

† Fauna Boreali-Americana, p. 273.

rocks, made their way into the North American mountains before our hunters, a similar alteration in the instincts of the sheep would doubtless have been brought about.

Wild elephants domesticated in a few years. — No animal affords a more striking illustration of the principal points which I have been endeavouring to establish than the elephant; for, in the first place, the wonderful sagacity with which he accommodates himself to the society of man, and the new habits which he contracts, are not the result of time, nor of modifications produced in the course of many generations. These animals will breed in captivity, as is now ascertained, in opposition to the vulgar opinion of many modern naturalists, and in conformity to that of the ancients *Ælian* and *Columella**: yet it has always been the custom, as the least expensive mode of obtaining them, to capture wild individuals in the forests, usually when full grown; and, in a few years after they are taken — sometimes, it is said, in the space of a few months — their education is completed.

Had the whole species been domesticated from an early period in the history of man, like the camel, their superior intelligence would, doubtless have been attributed to their long and familiar intercourse with the lord of the creation; but we know that a few years is sufficient to bring about this wonderful change of habits; and, although the same individual may continue to receive tuition for a century afterwards, yet it makes no further progress in the general development of its faculties. Were it otherwise, indeed, the

* Mr. Corse on the Habits, &c. of the Elephant, Phil. Trans.
1799.

animal would soon deserve more than the poet's epithet of "half-reasoning."

From the authority of our countrymen employed in the late Burmese war, it appears, in corroboration of older accounts, that, when elephants are required to execute extraordinary tasks, they may be made to understand that they will receive unusual rewards. Some favourite dainty is shown to them, in the hope of acquiring which the work is done; and so perfectly does the nature of the contract appear to be understood, that the breach of it, on the part of the master, is often attended with danger. In this case, a power has been given to the species to adapt their social instincts to new circumstances with surprising rapidity; but the extent of this change is defined by strict and arbitrary limits. There is no indication of a tendency to continued divergence from certain attributes with which the elephant was originally endued—no ground whatever for anticipating that, in thousands of centuries, any material alteration could ever be effected. All that we can infer from analogy is, that some more useful and peculiar races might probably be formed, if the experiment were fairly tried; and that some individual characteristic, now only casual and temporary, might be perpetuated by generation.

In all cases, therefore, where the domestic qualities exist in animals, they seem to require no lengthened process for their development; and they appear to have been wholly denied to some classes, which, from their strength and social disposition, might have rendered great services to man; as, for example, the greater part of the quadrupeds. The orang-outang, indeed, which, for its resemblance in form to man, and apparently for no other good reason, has been

assumed by Lamarck to be the most perfect of the inferior animals, has been tamed by the savages of Borneo, and made to climb lofty trees, and to bring down the fruit. But he is said to yield to his masters an unwilling obedience, and to be held in subjection only by severe discipline. We know nothing of the faculties of this animal which can suggest the idea that it rivals the elephant in intelligence ; much less any thing which can countenance the dreams of those who have fancied that it might have been transmuted into “the dominant race.” One of the baboons of Sumatra (*Simia carpolegus*) appears to be more docile, and is frequently trained by the inhabitants to ascend trees, for the purpose of gathering cocoa-nuts ; a service in which the animal is very expert. He selects, says Sir Stamford Raffles, the ripe nuts, with great judgment, and pulls no more than he is ordered.* The capuchin and cacajao monkeys are, according to Humboldt, taught to ascend trees in the same manner, and to throw down fruit on the banks of the lower Orinoco.†

It is for the Lamarckians to explain how it happens that those same savages of Borneo have not themselves acquired, by dint of longing, for many generations, for the power of climbing trees, the elongated arms of the orang, or even the prehensile tails of some American monkeys. Instead of being reduced to the necessity of subjugating stubborn and untractable brutes, we should naturally have anticipated “that their wants would have excited them to efforts, and that continued efforts would have given rise to new organs ;” or, rather

* Linn. Trans. vol. xiii. p. 244.

† Pers. Narr. of Travels to the Equinoctial Regions of the New Continent, in the years 1779—1804.

to the reorganization of organs which, in a manner
inconceivable with the principle of the *progressive*
~~species~~ have grown obsolete in tribes of men which
have such constant need of them.

Accommodation. — It follows, then, from the different
~~tribes~~ which have been considered in this chapter, that
a short period of time is generally sufficient to effect
nearly the whole change which an alteration of ex-
ternal circumstances can bring about in the habits of
a species, and that such capacity of accommodation to
new circumstances is enjoyed, in very different de-
grees, by different species.

Certain qualities appear to be bestowed exclusively
with a view to the relations which are destined to
exist between different species and, among others,
between certain species and man; but these latter are
always so nearly connected with the original habits
and propensities of each species in a wild state, that
they imply no indefinite capacity of varying from the
original type. The acquired habits derived from human
tuition are rarely transmitted to the offspring; and
when this happens, it is almost universally the case
with those merely which have some obvious connexion
with the attributes of the species when in a state of
independence.

CHAPTER IV.

WHETHER SPECIES HAVE A REAL EXISTENCE IN NATURE — *continued.*

Phenomena of hybrids — Hunter's opinions — Mules not strictly intermediate between parent species — Hybrid plants — Experiments of Kölreuter and Wiegmann — Vegetable hybrids prolific throughout several generations — Why rare in a wild state — De Candolle on hybrid plants — The phenomena of hybrids confirm the distinctness of species — Theory of the gradation in the intelligence of animals as indicated by the facial angle — Tiedemann on the brain of the foetus in mammalia assuming successively the form of the brain of fish, reptile, and bird — Bearing of this discovery on the theory of progressive development and transmutation — Recapitulation.

Phenomena of hybrids. — WE have yet to consider another class of phenomena, those relating to the production of hybrids, which have been regarded in a very different light with reference to their bearing on the question of the permanent distinctness of species ; some naturalists considering them as affording the strongest of all proofs in favour of the reality of species ; others, on the contrary, appealing to them as countenancing the opposite doctrine, that all the varieties of organization and instinct now exhibited in the animal and vegetable kingdoms may have been propagated from a small number of original types.

In regard to the mammifers and birds, it is found that no sexual union will take place between races which are remote from each other in their habits and organization; and it is only in species that are very nearly allied that such unions produce offspring. It may be laid down as a general rule, admitting of very few exceptions among quadrupeds, that the hybrid progeny is sterile; and there seem to be no well-authenticated examples of the continuance of the mule race beyond one generation. The principal number of observations and experiments relate to the mixed offspring of the horse and the ass; and in this case it is well established that the he-mule can generate, and the she-mule produce. Such cases occur in Spain and Italy, and much more frequently in the West Indies and New Holland; but these mules have never bred in cold climates, seldom in warm regions, and still more rarely in temperate countries.

The hybrid offspring of the she-ass and the stallion, the *γιννος* of Aristotle, and the hinnus of Pliny, differs from the mule, or the offspring of the ass and mare. In both cases, says Buffon, these animals retain more of the dam than of the sire, not only in the magnitude, but in the figure of the body; whereas, in the form of the head, limbs, and tail, they bear a greater resemblance to the sire. The same naturalist infers, from various experiments respecting cross-breeds between the he-goat and ewe, the dog and she-wolf, the goldfinch and canary-bird, that the male transmits his sex to the greatest number, and that the preponderance of males over females exceeds that which prevails where the parents are of the same species.

Hunter's opinion. — The celebrated John Hunter has observed, that the true distinction of species must

ultimately be gathered from their incapacity of propagating with each other, and producing offspring capable of again continuing itself. He was unwilling, however, to admit that the horse and the ass were of the same species, because some rare instances had been adduced of the breeding of mules, although he maintained that the wolf, the dog, and the jackal were all of one species; because he had found, by two experiments, that the dog would breed both with the wolf and the jackal; and that the mule, in each case, would breed again with the dog. In these cases, however, it may be observed, that there was always one parent at least of pure breed, and no proof was obtained that a true hybrid race could be perpetuated; a fact of which I believe no examples are yet recorded, either in regard to mixtures of the horse and ass, or any other of the mammalia.

Should the fact be hereafter ascertained, that two mules can propagate their kind, we must still inquire whether the offspring may not be regarded in the light of a monstrous birth, proceeding from some accidental cause, or, rather, to speak more philosophically, from some general law not yet understood, but which may not be permitted permanently to interfere with those laws of generation by which species may, in general, be prevented from becoming blended. If, for example, we discovered that the progeny of a mule race degenerated greatly, in the first generation, in force, sagacity, or any attribute necessary for its preservation in a state of nature, we might infer that, like a monster, it is a mere temporary and fortuitous variety. Nor does it seem probable that the greater number of such monsters could ever occur unless obtained by art; for, in Hunter's experiments, stratagem or force

was, in most instances, employed to bring about the irregular connexion.*

Mules not strictly intermediate between the parent species. — It seems rarely to happen that the mule offspring is truly intermediate in character between the two parents. Thus Hunter mentions that, in his experiments, one of the hybrid pups resembled the wolf much more than the rest of the litter; and we are informed by Wiegmann, that, in a litter lately obtained in the Royal Menagerie at Berlin, from a white pointer and a she-wolf, two of the cubs resembled the common wolf-dog, but the third was like a pointer with hanging ears.

There is undoubtedly a very close analogy between these phenomena and those presented by the inter-mixture of distinct races of the same species, both in the inferior animals and in man. Dr. Prichard, in his “Physical History of Mankind,” cites examples where the peculiarities of the parents have been transmitted very unequally to the offspring; as where children, entirely white, or perfectly black, have sprung from the union of the European and the negro. Sometimes the colour or other peculiarities of one parent, after having failed to show themselves in the immediate progeny, reappear in a subsequent generation; as where a white child is born of two black parents, the grandfather having been a white.†

The same author judiciously observes that, if different species mixed their breed, and hybrid races were often propagated, the animal world would soon present a scene of confusion; its tribes would be

* Phil. Trans. 1787. Additional Remarks, Phil. Trans. 1789.

† Prichard, vol. i. p 217.

everywhere blended together, and we should perhaps find more hybrid creatures than genuine and uncorrupted races.*

Hybrid plants—Kölreuter's experiments.—The history of the vegetable kingdom has been thought to afford more decisive evidence in favour of the theory of the formation of new and permanent species from hybrid stocks. The first accurate experiments in illustration of this curious subject appear to have been made by Kölreuter, who obtained a hybrid from two species of tobacco, *Nicotiana rustica* and *N. paniculata*, which differ greatly in the shape of their leaves, the colour of the corolla, and the height of the stem. The stigma of a plant of *N. rustica* was impregnated with the pollen of a plant of *N. paniculata*. The seed ripened, and produced a hybrid which was intermediate between the two parents, and which, like all the hybrids which this botanist brought up, had imperfect stamens. He afterwards impregnated this hybrid with the pollen of *N. paniculata*, and obtained plants which much more resembled the last. This he continued through several generations, until, by due perseverance, he actually changed the *Nicotiana rustica* into the *Nicotiana paniculata*.

The plan of impregnation adopted was the cutting off of the anthers of the plant intended for fructification before they had shed pollen, and then laying on foreign pollen upon the stigma.

Wiegmann's experiments.—The same experiment has since been repeated with success by Wiegmann, who found that he could bring back the hybrids to the exact likeness of either parent, by crossing them a sufficient number of times.

* Prichard, vol. i. p. 97.

The blending of the characters of the parent stocks, in many other of Wiegmann's experiments, was complete; the colour and shape of the leaves and flowers, and even the scent, being intermediate, as in the offspring of the two species of *verbascum*. An intermarriage, also, between the common onion and the leek (*Allium cepa* and *A. porrum*) gave a mule plant, which, in the character of its leaves and flowers, approached most nearly to the garden onion, but had the elongated bulbous root and smell of the leek.

The same botanist remarks, that vegetable hybrids, when not strictly intermediate, more frequently approach the female than the male parent species, *but they never exhibit characters foreign to both*. A recross with one of the original stocks generally causes the mule plant to revert towards that stock; but this is not always the case, the offspring sometimes continuing to exhibit the character of a full hybrid.

In general, the success attending the production and perpetuity of hybrids among plants depends, as in the animal kingdom, on the degree of proximity between the species intermarried. If their organization be very remote, impregnation never takes place; if somewhat less distant, seeds are formed, but always imperfect and sterile. The next degree of relationship yields hybrid seedlings, but these are barren; and it is only when the parent species are very nearly allied that the hybrid race may be perpetuated for several generations. Even in this case, the best authenticated examples seem confined to the crossing of hybrids with individuals of pure breed. In none of the experiments most accurately detailed does it appear that both the parents were mules.

Wiegmann diversified as much as possible his mode

of bringing about these irregular unions among plants. He often sowed parallel rows, near to each other, of the species from which he desired to breed; and, instead of mutilating, after Kölreuter's fashion, the plants of one of the parent stocks, he merely washed the pollen off their anthers. The branches of the plants in each row were then gently bent towards each other and intertwined; so that the wind, and numerous insects, as they passed from the flowers of one to those of the other species, carried the pollen and produced fecundation.

Vegetable hybrids why rare in a wild state. — The same observer saw a good exemplification of the manner in which hybrids may be formed in a state of nature. Some wallflowers and pinks had been growing in a garden, in a dry sunny situation; and their stigmas had been ripened so as to be moist, and to absorb pollen with avidity, although their anthers were not yet developed. These stigmas became impregnated by pollen blown from some other adjacent plants of the same species; but, had they been of different species, and not too remote in their organization, mule races must have resulted.

When, indeed, we consider how busily some insects have been shown to be engaged in conveying anther-dust from flower to flower, especially bees, flower-eating beetles, and the like, it seems a most enigmatical problem how it can happen that promiscuous alliances between distinct species are not perpetually occurring.

How continually do we observe the bees diligently employed in collecting the red and yellow powder by which the stamens of flowers are covered, loading it on their hind legs, and carrying it to their hive for the

purpose of feeding their young ! In thus providing for their own progeny, these insects assist materially the process of fructification.* Few persons need be reminded that the stamens in certain plants grow on different blossoms from the pistils ; and, unless the summit of the pistil be touched with the fertilizing dust, the fruit does not swell, nor the seed arrive at maturity. It is by the help of bees, chiefly, that the development of the fruit of many such species is secured, the powder which they have collected from the stamens being unconsciously left by them in visiting the pistils.

How often, during the heat of a summer's day, do we see the males of diœcious plants, such as the yew-tree, standing separate from the females, and sending off into the air, upon the slightest breath of wind, clouds of buoyant pollen ! That the zephyr should so rarely intervene to fecundate the plants of one species with the anther-dust of others, seems almost to realize the converse of the miracle believed by the credulous herdsmen of the Lusitanian mares —

*Ore omnes versæ in Zephyrum, stant rupibus altis
Exceptantque leves auras : et sæpe sine ullis
Conjugiis, vento gravidæ, mirabile dictu.†*

But, in the first place, it appears that there is a natural aversion in plants, as well as in animals, to irregular sexual unions ; and in most of the successful experiments in the animal and vegetable world, some violence has been used in order to procure impregnation. The stigma imbibes, slowly and reluctantly, the

* See Barton on the Geography of Plants, p. 67.

† Georg. lib. iii. 273.

granules of the pollen of another species, even when it is abundantly covered with it; and if it happen that, during this period, ever so slight a quantity of the anther-dust of its own species alight upon it, this is instantly absorbed, and the effect of the foreign pollen destroyed. Besides, it does not often happen that the male and female organs of fructification, in different species, arrive at a state of maturity at precisely the same time. Even where such synchronism does prevail, so that a cross impregnation is effected, the chances are very numerous against the establishment of a hybrid race.

If we consider the vegetable kingdom generally, it must be recollect that even of the seeds which are well ripened, a great part are either eaten by insects, birds, and other animals, or decay for want of room and opportunity to germinate. Unhealthy plants are the first which are cut off by causes prejudicial to the species, being usually stifled by more vigorous individuals of their own kind. If, therefore, the relative fecundity or hardiness of hybrids be in the least degree inferior, they cannot maintain their footing for many generations, even if they were ever produced beyond one generation in a wild state. In the universal struggle for existence, the right of the strongest eventually prevails; and the strength and durability of a race depends mainly on its prolificness, in which hybrids are acknowledged to be deficient.

Centaurea hybrida, a plant which never bears seed, and is supposed to be produced by the frequent inter-mixture of two well-known species of *Centaurea*, grows wild upon a hill near Turin. *Ranunculus lacerus*, also sterile, has been produced accidentally at Grenoble,

and near Paris, by the union of two Ranunculi; but this occurred in gardens.*

Mr. Herbert's experiments. — Mr. Herbert, in one of his ingenious papers on mule plants, endeavours to account for their non-occurrence in a state of nature, from the circumstance that all the combinations that were likely to occur have already been made many centuries ago, and have formed the various species of botanists; but in our gardens, he says, whenever species, having a certain degree of affinity to each other, are transported from different countries, and brought for the first time into contact, they give rise to hybrid species.† But we have no data, as yet, to warrant the conclusion, that a single permanent hybrid race has ever been formed, even in gardens, by the intermarriage of two allied species brought from distant habitations. Until some fact of this kind is fairly established, and a new species, capable of perpetuating itself in a state of perfect independence of man, can be pointed out, it seems reasonable to call in question entirely this hypothetical source of new species. That varieties do sometimes spring up from cross breeds, in a natural way, can hardly be doubted; but they probably die out even more rapidly than races propagated by grafts or layers.

Opinion of De Candolle. — De Candolle, whose opinion on a philosophical question of this kind deserves the greatest attention, has observed, in his Essay on Botanical Geography, that the *varieties* of plants range themselves under two general heads: those produced by external circumstances, and those formed by hybridity. After adducing various argu-

* Hon. and Rev. W. Herbert, Hort. Trans. vol. iv. p. 41.

† Ibid.

ments to show that neither of these causes can explain the permanent diversity of plants indigenous in different regions, he says, in regard to the crossing of races, "I can perfectly comprehend, without altogether sharing the opinion, that, where many species of the same genera occur near together, hybrid species may be formed, and I am aware that the great number of species of certain genera which are found in particular regions may be explained in this manner; but I am unable to conceive how any one can regard the same explanation as applicable to species which live naturally at great distances. If the three larches, for example, now known in the world, lived in the same localities, I might then believe that one of them was the produce of the crossing of the two others; but I never could admit that the Siberian species has been produced by the crossing of those of Europe and America. I see, then, that there exist, in organized beings, permanent differences which cannot be referred to any one of the actual causes of variation, and these differences are what constitute *species*."*

Reality of species confirmed by the phenomena of hybrids. — The most decisive arguments, perhaps, amongst many others, against the probability of the derivation of permanent species from cross-breeds, are to be drawn from the fact alluded to by De Candolle, of species having a close affinity to each other occurring in distinct botanical provinces, or countries inhabited by groups of distinct species of indigenous plants: for in this case naturalists, who are not prepared to go the whole length of the transmutationists, are under the necessity of admitting that, in some

* * *Essai Élémentaire, &c., 3me partie.*

cases, species which approach very near to each other in their characters, were so created from their origin ; an admission fatal to the idea of its being a general law of nature, that a few original types only should be formed, and that all intermediate races should spring from the intermixture of those stocks.

This notion, indeed, is wholly at variance with all that we know of hybrid generation ; for the phenomena entitle us to affirm, that had the types been at first somewhat distant, *no cross-breeds would ever have been produced*, much less those prolific races which we now recognize as distinct species.

In regard, moreover, to the permanent propagation of hybrid races among animals, insuperable difficulties present themselves, when we endeavour to conceive the blending together of the different instincts and propensities of two species, so as to insure the preservation of the intermediate race. The common mule, when obtained by human art, may be protected by the power of man ; but, in a wild state, it would not have precisely the same wants either as the horse or the ass : and if, in consequence of some difference of this kind, it strayed from the herd, it would soon be hunted down by beasts of prey, and destroyed.

If we take some genus of insects, such as the bee, we find that each of the numerous species has some difference in its habits, its mode of collecting honey, or constructing its dwelling, or providing for its young, and other particulars. In the case of the common hive-bee, the workers are described, by Kirby and Spence, as being endowed with no less than thirty distinct instincts.* So also we find that, amongst a most

* Intr. to Entom., vol. ii. p. 504. Ed. 1817.

numerous class of spiders, there are nearly as many different modes of spinning their webs as there are species. When we recollect how complicated are the relations of these instincts with co-existing species, both of the animal and vegetable kingdoms, it is scarcely possible to imagine that a bastard race could spring from the union of two of these species, and retain just so much of the qualities of each parent stock as to preserve its ground in spite of the dangers which surround it.

We might also ask, if a few generic types alone have been *created* among insects, and the intermediate species have proceeded from hybridity, where are those original types, combining, as they ought to do, the elements of all the instincts which have made their appearance in the numerous derivative races? So also in regard to animals of all classes, and of plants; if species in general are of hybrid origin, where are the stocks which combine in themselves the habits, properties, and organs, of which all the intervening species ought to afford us mere modifications?

Recapitulation of the arguments from hybrids. — I shall now conclude this subject by summing up, in a few words, the results to which I have been led by the consideration of the phenomena of hybrids. It appears, that the aversion of individuals of distinct species to the sexual union is common to animals and plants; and that it is only when the species approach near to each other in their organization and habits, that any offspring are produced from their connexion. Mules are of extremely rare occurrence in a state of nature, and no examples are yet known of their having pro-created in a wild state. But it has been proved, that hybrids are not universally sterile, provided the parent

stocks have a near affinity to each other, although the continuation of the mixed race, for several generations, appears hitherto to have been obtained only by crossing the hybrids with individuals of pure species; an experiment which by no means bears out the hypothesis that a true hybrid race could ever be permanently established.

Hence we may infer, that aversion to sexual intercourse is, in general, a good test of the distinctness of original stocks, or of *species*; and the procreation of hybrids is a proof of the very near affinity of species. Perhaps, hereafter, the number of generations for which hybrids may be continued, before the race dies out (for it seems usually to degenerate rapidly), may afford the zoologist and botanist an experimental test of the difference in the degree of affinity of allied species.

I may also remark, that if it could have been shown that a single permanent species had ever been produced by hybridity (of which there is no satisfactory proof), it might certainly have lent some countenance to the notions of the ancients respecting the gradual deterioration of created things, but none whatever to Lamarck's theory of their progressive perfectibility; for observations have hitherto shown that there is a tendency in mule animals and plants to degenerate in organization.

It was before remarked, that the theory of progressive development arose from an attempt to ingraft the doctrines of the transmutationists upon one of the most popular generalizations in geology. But modern geological researches have almost destroyed every appearance of that gradation in the successive groups of animate beings, which was supposed to indicate the

slow progress of the organic world from the more simple to the more compound structure. In the more modern formations, we find clear indications that the highest orders of the terrestrial mammalia were fully represented during several successive epochs; but in the monuments which we have hitherto examined of more remote eras, in which there are as yet discovered few fluviatile, and lacustrine formations, and, therefore, scarcely any means of obtaining an insight into the zoology of the continents then existing, we have only as yet found in one locality two or three examples of mammiferous quadrupeds.* The recent origin of man, and the absence of all signs of any rational being holding an analogous relation to former states of the animate world, affords one, and the only reasonable argument, in support of the hypothesis of a progressive scheme; but none whatever in favour of the fancied evolution of one species out of another.

Theory of the gradation in intellect as shown by the facial angle.—When the celebrated anatomist, Camper, first attempted to estimate the degrees of sagacity of different animals, and of the races of man, by the measurement of the facial angle, some speculators were bold enough to affirm, that certain simiae differed as little from the more savage races of men, as those do from the human race in general; and that a scale might be traced from “apes with foreheads villainous low” to the African variety of the human species, and from that to the European. The facial angle was measured by drawing a line from the prominent centre of the forehead to the most advanced part of the lower jaw-bone, and observing the angle which it made with

* See account of an opossum and another marsupial genus found at Stonesfield, book i. chap. ix...

the horizontal line; and it was affirmed, that there was a regular series of such angles from birds to the mammalia.

The gradation from the dog to the monkey was said to be perfect, and from that again to man. One of the ape tribe has a facial angle of 42° ; and another, which approximated nearest to man in figure, an angle of 50° . To this succeeds (*longo sed proximus intervallo*) the head of the African negro, which, as well as that of the Kalmuc, forms an angle of 70° ; while that of the European contains 80° . The Roman painters preferred the angle of 95° ; and the character of beauty and sublimity, so striking in some works of Grecian sculpture, as in the head of the Apollo, and in the Medusa of Sisocles, is given by an angle which amounts to 100° . *

A great number of valuable facts and curious analogies in comparative anatomy were brought to light during the investigations which were made by Camper, John Hunter, and others, to illustrate this scale of organization; and their facts and generalizations must not be confounded with the fanciful systems which White and others deduced from them.†

That there is some connexion between an elevated and capacious forehead, in certain races of men, and a large development of the intellectual faculties, seems highly probable; and that a low facial angle is frequently accompanied with inferiority of mental powers, is certain; but the attempt to trace a graduated scale of intelligence through the different species of animals accompanying the modifications of the form of the skull, is a mere visionary speculation. It has been

* Prichard's Phys. Hist. of Mankind, vol. i. p. 159.

† Ch. White on the Regular Gradation in Man, &c., 1799.

found necessary to exaggerate the sagacity of the ape tribe at the expense of the dog ; and strange contradictions have arisen in the conclusions deduced from the structure of the elephant ; some anatomists being disposed to deny the quadruped the intelligence which he really possesses, because they found that the volume of his brain was small in comparison to that of the other mammalia ; while others were inclined to magnify extravagantly the superiority of his intellect, because the vertical height of his skull is so great when compared to its horizontal length.

Different races of men are all of one species. — It would be irrelevant to our subject if we were to enter into a further discussion on these topics ; because, even if a graduated scale of organization and intelligence could have been established, it would prove nothing in favour of a tendency, in each species, to attain a higher state of perfection. I may refer the reader to the writings of Blumenbach, Prichard, Lawrence, and others, for convincing proofs that the varieties of form, colour, and organization of different races of men, are perfectly consistent with the generally received opinion, that all the individuals of the species have originated from a single pair ; and, while they exhibit in man as many diversities of a physiological nature as appear in any other species, they confirm also the opinion of the slight deviation from a common standard of which species are capable.

The power of existing and multiplying in every latitude, and in every variety of situation and climate, which has enabled the great human family to extend itself over the habitable globe, is partly, says Lawrence, the result of physical constitution, and partly of the mental prerogative of man. If he did not possess the

most enduring and flexible corporeal frame, his arts would not enable him to be the inhabitant of all climates, and to brave the extremes of heat and cold, and the other destructive influences of local situation.* Yet, notwithstanding this flexibility of bodily frame, we find no signs of indefinite departure from a common standard, and the intermarriages of individuals of the most remote varieties are not less fruitful than between those of the same tribe.

Tiedemann on the brain of the foetus in vertebrated animals. — There is yet another department of anatomical discovery to which I must allude, because it has appeared to some persons to afford a distant analogy, at least, to that progressive development by which some of the inferior species may have been gradually perfected into those of more complex organization. Tiedemann found, and his discoveries have been most fully confirmed and elucidated by M. Serres, that the brain of the foetus, in the highest class of vertebrated animals, assumes, in succession, forms analogous to those which belong to fishes, reptiles, and birds, before it acquires the additions and modifications which are peculiar to the mammiferous tribe. So that, in the passage from the embryo to the perfect mammifer, there is a typical representation, as it were, of all those transformations which the primitive species are supposed to have undergone, during a long series of generations, between the present period and the remotest geological era.

If you examine the brain of the mammalia, says M. Serres, at an early stage of uterine life, you per-

* Lawrence, Lectures on Phys. Zool. and Nat. Hist. of Man, p. 192. Ed. 1823,

ceive the cerebral hemispheres consolidated, as in fish, in two vesicles, isolated one from the other; at a later period, you see them affect the configuration of the cerebral hemispheres of reptiles; still later again, they present you with the forms of those of birds; finally, they acquire, at the era of birth, and sometimes later, the permanent forms which the adult mammalia present.

The cerebral hemispheres, then, arrive at the state which we observe in the higher animals only by a series of successive metamorphoses. If we reduce the whole of these evolutions to four periods, we shall see, that in the first are born the cerebral lobes of fishes; and this takes place homogeneously in all classes. The second period will give us the organization of reptiles; the third, the brain of birds; and the fourth, the complex hemispheres of mammalia.

If we could develop the different parts of the brain of the inferior classes, we should make, in succession, a reptile out of a fish, a bird out of a reptile, and a mammiferous quadruped out of a bird. If, on the contrary, we could starve this organ in the mammalia, we might reduce it successively to the condition of the brain of the three inferior classes.

Nature often presents us with this last phenomenon in monsters, but never exhibits the first. Among the various deformities which organized beings may experience, they never pass the limits of their own classes to put on the forms of the class above them. Never does a fish elevate itself so as to assume the form of the brain of a reptile; nor does the latter ever attain that of birds; nor the bird that of the mammifer. It may happen that a monster may have two heads; but

the conformation of the brain always remains circumscribed narrowly within the limits of its class.*

Bearing of these discoveries on the theory of progressive development. — It will be observed, that these curious phenomena disclose, in a highly interesting manner, the unity of plan that runs through the organization of the whole series of vertebrated animals ; but they lend no support whatever to the notion of a gradual transmutation of one species into another ; least of all of the passage, in the course of many generations, from an animal of a more simple to one of a more complex structure. On the contrary, were it not for the sterility imposed on monsters, as well as on hybrids in general, the argument to be derived from Tiedemann's discovery, like that deducible from experiments respecting hybridity, would be in favour of the successive *degeneracy*, rather than the perfectibility, in the course of ages, of certain classes of organic beings.

Recapitulation. — For the reasons, therefore, detailed in this and the two preceding chapters, we may draw the following inferences in regard to the reality of *species* in nature : —

1st. That there is a capacity in all species to accommodate themselves, to a certain extent, to a change of external circumstances, this extent varying greatly, according to the species.

2dly. When the change of situation which they can endure is great, it is usually attended by some modifications of the form, colour, size, structure, or other particulars ; but the mutations thus superinduced are

* E. R. A. Serres, *Anatomie Comparée du Cerveau*, illustrated by numerous plates, tome i., 1824,

governed by constant laws, and the capability of so varying forms part of the permanent specific character.

3dly. Some acquired peculiarities of form, structure, and instinct, are transmissible to the offspring; but these consist of such qualities and attributes only as are intimately related to the natural wants and propensities of the species.

4thly. The entire variation from the original type, which any given kind of change can produce, may usually be effected in a brief period of time, after which no farther deviation can be obtained by continuing to alter the circumstances, though ever so gradually; indefinite divergence, either in the way of improvement or deterioration, being prevented, and the least possible excess beyond the defined limits being fatal to the existence of the individual.

5thly. The intermixture of distinct species is guarded against by the aversion of the individuals composing them to sexual union, or by the sterility of the mule offspring. It does not appear that true hybrid races have ever been perpetuated for several generations, even by the assistance of man; for the cases usually cited relate to the crossing of mules with individuals of pure species, and not to the intermixture of hybrid with hybrid.

6thly. From the above considerations, it appears that species have a real existence in nature; and that each was endowed, at the time of its creation, with the attributes and organization by which it is now distinguished.

CHAPTER V.

LAWS WHICH REGULATE THE GEOGRAPHICAL DISTRIBUTION OF SPECIES.

Analogy of climate not attended with identity of species — Botanical geography — Stations — Habitations — Distinct provinces of indigenous plants — Vegetation of islands — Marine vegetation — In what manner plants become diffused — Effects of wind, rivers, marine currents — Agency of animals — Many seeds pass through the stomachs of animals and birds undigested — Agency of man in the dispersion of plants, both voluntary and involuntary — Its analogy to that of the inferior animals.

Next to determining the question whether species have a real existence, the consideration of the laws which regulate their geographical distribution is a subject of primary importance to the geologist. It is only by studying these laws with attention, by observing the positions which groups of species occupy at present, and inquiring how these may be varied in the course of time by migrations, by changes in physical geography, and other causes, that we can hope to learn whether the duration of species be limited, or in what manner the state of the animate world is affected by the endless vicissitudes of the inanimate.

Different regions inhabited by distinct species. — That different regions of the globe are inhabited by entirely distinct animals and plants, is a fact which has been

familiar to all naturalists since Buffon first pointed out the want of *specific* identity between the land quadrupeds of America and those of the Old World. The same phenomenon has, in later times, been forced in a striking manner upon our attention, by the examination of New Holland, where the indigenous species of animals and plants were found to be, almost without exception, distinct from those known in other parts of the world.

But the extent of this parcelling out of the globe amongst different *nations*, as they have been termed, of plants and animals — the universality of a phenomenon so extraordinary and unexpected, may be considered as one of the most interesting facts clearly established by the advance of modern science.

Scarcely fourteen hundred species of plants appear to have been known and described by the Greeks, Romans, and Arabians. At present, more than three thousand species are enumerated, as natives of our own island.* In other parts of the world there have been collected, perhaps, upwards of seventy thousand species. It was not to be supposed, therefore, that the ancients should have acquired any correct notions respecting what may be called the geography of plants, although the influence of climate on the character of the vegetation could hardly have escaped their observation.

Antecedently to investigation, there was no reason for presuming that the vegetable productions, growing wild in the eastern hemisphere, should be unlike those of the western, in the same latitude; nor that the plants of the Cape of Good Hope should be unlike

* Barton's Lectures on the Geography of Plants, p. 2., 1827.

those of the South of Europe; situations where the climate is little dissimilar. The contrary supposition would have seemed more probable, and we might have anticipated an almost perfect identity in the animals and plants which inhabit corresponding parallels of latitude. The discovery, therefore, that each separate region of the globe, both of the land and water, is occupied by distinct groups of species, and that most of the exceptions to this general rule may be referred to disseminating causes now in operation, is eminently calculated to excite curiosity, and to stimulate us to seek some hypothesis respecting the first introduction of species which may be reconcileable with such phenomena.

Botanical geography.—A comparison of the *plants* of different regions of the globe affords results more to be depended upon in the present state of our knowledge than those relating to the animal kingdom, because the science of botany is more advanced, and probably comprehends a great proportion of the total number of the vegetable productions of the whole earth. Humboldt, in several eloquent passages of his Personal Narrative, was among the first to promulgate philosophical views on this subject. Every hemisphere, says this traveller, produces plants of different species; and it is not by the diversity of climates that we can attempt to explain why equinoctial Africa has no laurineæ, and the New World no heaths; why the calceolariae are found only in the southern hemisphere; why the birds of the continent of India glow with colours less splendid than the birds of the hot parts of America; finally, why the tiger is peculiar to Asia, and the ornithorhynchus to New Holland.*

* Pers. Nar., vol. v. p. 180.

"We can conceive," he adds, "that a small number of the families of plants, for instance, the musaceæ and the palms, cannot belong to very cold regions, on account of their internal structure and the importance of certain organs; but we cannot explain why no one of the family of melastomas vegetates north of the parallel of thirty degrees; or why no rose-tree belongs to the southern hemisphere. Analogy of climates is often found in the two continents without identity of productions." *

The luminous essay of De Candolle on "Botanical Geography" presents us with the fruits of his own researches and those of Humboldt, Brown, and other eminent botanists, so arranged, that the principal phenomena of the distribution of plants are exhibited in connexion with the causes to which they are chiefly referable. † "It might not, perhaps, be difficult," observes this writer, "to find two points, in the United States and in Europe, or in equinoctial America and Africa, which present all the same circumstances: as, for example, the same temperature, the same height above the sea, a similar soil, an equal dose of humidity; yet nearly all, *perhaps all*, the plants in these two similar localities shall be distinct. A certain degree of analogy, indeed, of aspect, and even of structure, might very possibly be discoverable between the plants of the two localities in question; but the *species* would in general be different. Circumstances, therefore, different from those which now determine the *stations*, have had an influence on the *habitations* of plants."

* Pers. Nar., vol. v. p. 180.

† Essai Élémentaire de Géographie Botanique. Extrait du 18me vol. du Dict. des Sci. Nat.

Stations and habitations of plants. — As I shall frequently have occasion to speak of the *stations* and *habitations* of plants in the technical sense in which the terms are used in the above passage, I may remind the geologist that station indicates the peculiar nature of the locality where each species is accustomed to grow, and has reference to climate, soil, humidity, light, elevation above the sea, and other analogous circumstances ; whereas, by habitation is meant a general indication of the country where a plant grows wild. Thus the *station* of a plant may be a salt-marsh, in a temperate climate, a hill-side, the bed of the sea, or a stagnant pool. Its *habitation* may be Europe, North America, or New Holland between the tropics. The study of stations has been styled the topography, that of habitations the geography, of botany. The terms thus defined, express each a distinct class of ideas, which have been often confounded together, and which are equally applicable in zoology.

In further illustration of the principle above alluded to, that difference of longitude, independently of any influence of temperature, is accompanied by a great, and sometimes a complete, diversity in the species of plants, De Candolle observes, that, out of 2891 species of phænogamous plants described by Pursh, in the United States, there are only 385 which are found in northern or temperate Europe. MM. Humboldt and Bonpland, in all their travels through equinoctial America, found only twenty-four species (these being all cyperaceæ and gramineæ) common to America and any part of the Old World. On comparing New Holland with Europe, Mr. Brown ascertained that, out of 4100 species, discovered in Australia, there were only

166 common to Europe, and of this small number there were some few which may have been transported thither by man.

But it is still more remarkable, that in the more widely separated parts of the ancient continent, notwithstanding the existence of an uninterrupted land-communication, the diversity in the specific character of the respective vegetations is almost as striking. Thus there is found one assemblage of species in China, another in the countries bordering the Black Sea and the Caspian, a third in those surrounding the Mediterranean, a fourth in the great platforms of Siberia and Tartary, and so forth.

The distinctness of the groups of indigenous plants, in the same parallel of latitude, is greatest where continents are disjoined by a wide expanse of ocean. In the northern hemisphere, near the pole, where the extremities of Europe, Asia, and America unite or approach near to one another, a considerable number of the same species of plants are found, common to the three continents. But it has been remarked, that these plants, which are thus so widely diffused in the Arctic regions, are also found in the chain of the Aleutian islands, which stretch almost across from America to Asia, and which may probably have served as the channel of communication for the partial blending of the Floras of the adjoining regions. It has, indeed, been found to be a general rule, that plants found at two points very remote from each other occur also in places intermediate.

Vegetation of islands. — In islands very distant from continents the total number of plants is comparatively small; but a large proportion of the species are such

as occur nowhere else. In so far as the Flora of such islands is not peculiar to them, it contains, in general, species common to the nearest main lands.*

The islands of the great southern ocean exemplify these rules; the easternmost containing more American, and the western more Indian, plants.† Madeira and Teneriffe contain many species, and even entire genera, peculiar to them ; but they have also plants in common with Portugal, Spain, the Azores, and the north-west coast of Africa.‡

In the Canaries, out of 533 species of phænogamous plants, it is said that 310 are peculiar to these islands, and the rest identical with those of the African continent ; but in the Flora of St. Helena, which is so far distant even from the western shores of Africa, there have been found, out of sixty-one native species, only *two or three* which are to be found in any other part of the globe.

Number of botanical provinces. — De Candolle has enumerated twenty great botanical provinces inhabited by indigenous or aboriginal plants ; and although many of these contain a variety of species which are common to several others, and sometimes to places very remote, yet the lines of demarcation are, upon the whole, astonishingly well defined.§ Nor is it likely that the bearing of the evidence on which these general views are founded will ever be materially affected, since they

* Prichard, vol. i. p. 36. Brown, Appendix to Flinders.

† Forster, Observations, &c.

‡ Humboldt, Pers. Nar., vol. i. p. 270. of the translation.
Prichard, Phys. Hist. of Mankind, vol. i. p. 37.

§ See a farther subdivision, by which twenty-seven provinces are made, by M. Alph. De Candolle, son of De Candolle. Monogr. des Campanulées. Paris, 1830.

are already confirmed by the examination of seventy or eighty thousand species of plants.

The entire change of opinion which the contemplation of these phenomena has brought about is worthy of remark. The first travellers were persuaded that they should find, in distant regions, the plants of their own country, and they took a pleasure in giving them the same names. It was some time before this illusion was dissipated ; but so fully sensible did botanists at last become of the extreme smallness of the number of phænogamous plants common to different continents, that the ancient Floras fell into disrepute. All grew diffident of the pretended identifications ; and we now find that every naturalist is inclined to examine each supposed exception with scrupulous severity.* If they admit the fact, they begin to speculate on the mode whereby the seeds may have been transported from one country into the other, or inquire on which of two continents the plant was indigenous, assuming that a species, like an individual, cannot have two birth-places.

Marine vegetation. — The marine vegetation is less known ; but we learn from Lamouroux, that it is divisible into different systems, apparently as distinct as those on the land, notwithstanding that the uniformity of temperature is so much greater in the ocean. For on that ground we might have expected the phenomenon of partial distribution to have been far less striking, since climate is, in general, so influential a cause in checking the dispersion of species from one zone to another.

The number of hydrophytes, as they are termed, is

* De Candolle, *Essai Elément. de Géog. Botan.*, p. 45.

very considerable, and their stations are found to be infinitely more varied than could have been anticipated; for while some plants are covered and uncovered daily by the tide, others live in abysses of the ocean, at the extraordinary depth of one thousand feet ; and although in such situations there must reign darkness more profound than night, at least to our organs, many of these vegetables are highly coloured. From the analogy of terrestrial plants we might have inferred, that the colouring of the algæ was derived from the influence of the solar rays ; yet we are compelled to doubt when we reflect how feeble must be the rays which penetrate to these great depths.

The subaqueous vegetation of the Mediterranean is, upon the whole, distinct from that of the Atlantic on the west, and that part of the Arabian gulf which is immediately contiguous on the south. Other botanical provinces are found in the West Indian seas, including the gulf of Mexico ; in the ocean which washes the shores of South America ; in the Indian Ocean and its gulfs ; in the seas of Australia ; and in the Atlantic basin, from the 40th degree of north latitude to the pole. There are very few species common to the coast of Europe and the United States of North America, and none common to the Straits of Magellan and the shores of Van Diemen's Land.

It must not be overlooked, that the distinctness alluded to between the vegetation of these several countries relates strictly to *species*, and not to forms. In regard to the numerical preponderance of certain forms, and many peculiarities of internal structure, there is a marked agreement in the vegetable productions of districts placed in corresponding latitudes, and under similar physical circumstances, however remote

their position. Thus there are innumerable points of analogy between the vegetation of the Brazils, equinoctial Africa, and India ; and there are also points of difference wherein the plants of these regions are distinguishable from all extra-tropical groups. But there are very few species common to the three continents. The same may be said, if we compare the plants of the United States with that of the middle of Europe : the species are distinct, but the forms are in a great degree analogous.

Let us now consider what means of diffusion, independently of the agency of man, are possessed by plants, whereby, in the course of ages, they may be enabled to stray from one of the botanical provinces above mentioned to another, and to establish new colonies at a great distance from their birth-place.

Manner in which plants become diffused.—Winds.—The principal of the inanimate agents provided by nature for scattering the seeds of plants over the globe, are the movements of the atmosphere and of the ocean, and the constant flow of water from the mountains to the sea. To begin with the winds : a great number of seeds are furnished with downy and feathery appendages, enabling them, when ripe, to float in the air, and to be wafted easily to great distances by the most gentle breeze. Other plants are fitted for dispersion by means of an attached wing, as in the case of the fir-tree, so that they are caught up by the wind as they fall from the cone, and are carried to a distance. Amongst the comparatively small number of plants known to Linnæus, no less than 138 genera are enumerated as having winged seeds.

As winds often prevail for days, weeks, or even months together, in the same direction, these means

of transportation may sometimes be without limits ; and even the heavier grains may be borne through considerable spaces, in a very short time, during ordinary tempests ; for strong gales, which can sweep along grains of sand, often move at the rate of about forty miles an hour, and if the storm be very violent, at the rate of fifty-six miles.* The hurricanes of tropical regions, which root up trees and throw down buildings, sweep along at the rate of ninety miles an hour ; so that, for however short a time they prevail, they may carry even the heavier fruits and seeds over friths and seas of considerable width, and, doubtless, are often the means of introducing into islands the vegetation of adjoining continents. Whirlwinds are also instrumental in bearing along heavy vegetable substances to considerable distances. Slight ones may frequently be observed in our fields, in summer, carrying up haycocks into the air, and then letting fall small tufts of hay far and wide over the country ; but they are sometimes so powerful as to dry up lakes and ponds, and to break off the boughs of trees, and carry them up in a whirling column of air.

Franklin tells us, in one of his letters, that he saw, in Maryland, a whirlwind which began by taking up the dust which lay in the road, in the form of a sugar-loaf with the pointed end downwards, and soon after grew to the height of forty or fifty feet, being twenty or thirty in diameter. It advanced in a direction contrary to the wind ; and although the rotatory motion of the column was surprisingly rapid, its onward progress was sufficiently slow to allow a man to keep pace with it on foot. Franklin followed it on horseback, accom-

* Annuaire du Bureau des Longitudes.

panied by his son, for three quarters of a mile, and saw it enter a wood, where it twisted and turned round large trees with surprising force. These were carried up in a spiral line, and were seen flying in the air, together with boughs and innumerable leaves, which, from their height, appeared reduced to the apparent size of flies. As this cause operates at different intervals of time throughout a great portion of the earth's surface, it may be the means of bearing not only plants but insects, land-testacea and their eggs, with many other species of animals, to points which they could never otherwise have reached, and from which they may then begin to propagate themselves again as from a new centre.

Distribution of cryptogamous plants. — It has been found that a great numerical proportion of the exceptions to the limitation of species to certain quarters of the globe occur in the various tribes of cryptogamic plants. Linnæus observed that, as the germs of plants of this class, such as mosses, fungi, and lichens, consist of an impalpable powder, the particles of which are scarcely visible to the naked eye, there is no difficulty to account for their being dispersed throughout the atmosphere, and carried to every point of the globe, where there is a station fitted for them. Lichens in particular ascend to great elevations, sometimes growing two thousand feet above the line of perpetual snow, at the utmost limits of vegetation, and where the mean temperature is nearly at the freezing point. This elevated position must contribute greatly to facilitate the dispersion of those buoyant particles of which their fructification consists.*

* Linn., *Tour in Lapland*, vol. ii. p. 282.

Some have inferred, from the springing up of mushrooms whenever particular soils and decomposed organic matter are mixed together, that the production of fungi is accidental, and not analogous to that of perfect plants. But Fries, whose authority on these questions is entitled to the highest respect, has shown the fallacy of this argument in favour of the old doctrine of equivocal generation. "The sporules of fungi," says this naturalist, "are so infinite, that in a single individual of *Reticularia maxima*, I have counted above ten millions, and so subtle as to be scarcely visible, often resembling thin smoke; so light that they may be raised perhaps by evaporation into the atmosphere, and dispersed in so many ways by the attraction of the sun, by insects, wind, elasticity, adhesion, &c., that it is difficult to conceive a place from which they may be excluded."*

Agency of rivers and currents. — In considering, in the next place, the instrumentality of the aqueous agents of dispersion, I cannot do better than cite the words of one of our ablest botanical writers. "The mountain stream or torrent," observes Keith, "washes down to the valley the seeds which may accidentally fall into it, or which it may happen to sweep from its banks when it suddenly overflows them. The broad and majestic river, winding along the extensive plain, and traversing the continents of the world, conveys to the distance of many hundreds of miles the seeds that may have vegetated at its source. Thus the southern shores of the Baltic are visited by seeds which grew in the interior of Germany; and the western shores of the Atlantic by seeds that have been generated in the

* Fries, cited by Lindley, *Introd. to Nat. Syst. of Botany.*

interior of America."* Fruits, moreover, indigenous to America and the West Indies, such as that of the *Mimosa scandens*, the cashew-nut, and others, have been known to be drifted across the Atlantic by the Gulf stream, on the western coasts of Europe, in such a state that they might have vegetated had the climate and soil been favourable. Among these the *Guilandina Bonduc*, a leguminous plant, is particularly mentioned; as having been raised from a seed found on the west coast of Ireland.†

Sir Hans Sloane states, that several kinds of beans cast ashore on the Orkney Isles, and Ireland, but none of which appear to have naturalized themselves, are derived from trees which grow in the West Indies, and many of them in Jamaica. He conjectures that they may have been conveyed by rivers into the sea, and then by the Gulf stream to greater distances, in the same manner as the sea-weed called *Lenticula marina*, or Sargasso, which grows on the rocks about Jamaica, is known to be "carried by the winds and current towards the coast of Florida, and thence into the North American ocean, where it lies very thick on the surface of the sea."‡

The absence of liquid matter in the composition of seeds renders them comparatively insensible to heat and cold, so that they may be carried without detriment through climates where the plants themselves would instantly perish. Such is their power of resisting the effects of heat, that Spallanzani mentions some seeds that germinated after having been boiled in

* System of Physiological Botany, vol. ii. p. 405.

† Brown, Append. to Tuckey, No. V. p. 481.

‡ Phil. Trans. 1696.

water.* Sir John Herschel informs me that he has sown at the Cape of Good Hope the seeds of the *Acacia lophanta* after they had remained for twelve hours in water of 140° Fahrenheit, and they germinated far more rapidly than unboiled seeds. He also states that an eminent botanist, Baron Ludwig, could not get the seeds of a species of cedar to grow at the Cape till they were thoroughly boiled.

When, therefore, a strong gale, after blowing violently off the land for a time, dies away, and the seeds alight upon the surface of the waters, or wherever the ocean, by eating away the sea-cliffs, throws down into its waves plants which would never otherwise reach the shores, the tides and currents become active instruments in assisting the dissemination of almost all classes of the vegetable kingdom.

In a collection of six hundred plants from the neighbourhood of the river Zaire, in Africa, Mr. Brown found that thirteen species were also met with on the opposite shores of Guiana and Brazil. He remarked that most of these plants were found only on the lower parts of the river Zaire, and were chiefly such as produced seeds capable of retaining their vitality a long time in the currents of the ocean.

The migration of plants aided by islands. — Islands, moreover, and even the smallest rocks, play an important part in aiding such migrations; for when seeds alight upon them from the atmosphere, or are thrown up by the surf, they often vegetate, and supply the winds and waves with a repetition of new and uninjured crops of fruit and seeds. These may afterwards pursue their course through the atmosphere, or along the surface of the sea, in the same direction.

* System of Physiological Botany, vol. ii. p. 403.

The number of plants found at any given time on an islet affords us no test whatever of the extent to which it may have co-operated towards this end, since a variety of species may first thrive there and then perish, and be followed by other chance-comers like themselves.

Currents and winds in the arctic regions drift along icebergs covered with an alluvial soil, on which herbs and pine-saplings are seen growing, which may often continue to vegetate on some distant shore where the ice-island is stranded.

Dispersion of marine plants. — With respect to marine vegetation, the seeds, being in their native element, may remain immersed in water without injury for indefinite periods, so that there is no difficulty in conceiving the diffusion of species wherever uncongenial climates, contrary currents, and other causes do not interfere. All are familiar with the sight of the floating sea-weed,

“ Flung from the rock on ocean’s foam to sail,
Where’er the surge may sweep, the tempest’s breath prevail.”

Remarkable accumulations of that species of sea-weed generally known as gulf-weed, or sargasso, occur on each side of the equator in the Atlantic, Pacific, and Indian Oceans. Columbus and other navigators, who first encountered these banks of algæ in the Northern Atlantic, compared them to vast inundated meadows, and state that they retarded the progress of their vessels. The most extensive bank is a little west of the meridian of Fayal, one of the Azores, between latitudes 35° and 36° : violent north winds sometimes prevail in this space, and drive the sea-

weed to low latitudes, as far as the 24th or even the 20th degree.*

The hollow pod-like receptacles in which the seeds of many algae are lodged, and the filaments attached to the seed-vessels of others, seem intended to give buoyancy; and I may observe that these hydrophytes are in general *proliferous*, so that the smallest fragment of a branch can be developed into a perfect plant. The seeds, moreover, of the greater number of species are enveloped with a mucous matter like that which surrounds the eggs of some fish, and which not only protects them from injury, but serves to attach them to floating bodies or to rocks.

Agency of animals in the distribution of plants.— But we have as yet considered part only of the fertile resources of nature for conveying seeds to a distance from their place of growth. The various tribes of animals are busily engaged in furthering an object whence they derive such important advantages. Sometimes an express provision is found in the structure of seeds to enable them to adhere firmly by prickles, hooks, and hairs, to the coats of animals, or feathers of the winged tribe, to which they remain attached for weeks, or even months, and are borne along into every region whither birds or quadrupeds may migrate. Linnæus enumerates fifty genera of plants, and the number now known to botanists is much greater, which are armed with hooks, by which, when ripe, they adhere to the coats of animals. Most of these vegetables, he remarks, require a soil enriched with dung. Few have failed to mark the locks of wool hanging on the thorn-bushes, wherever the sheep pass, and it is

* Greville, *Introduction to Algæ Britannicæ*, p. 12.

probable that the wolf or lion never give chase to herbivorous animals without being unconsciously subservient to this part of the vegetable economy.

A deer has strayed from the herd when browsing on some rich pasture, when he is suddenly alarmed by the approach of his foe. He instantly takes to flight, dashing through many a thicket, and swimming across many a river and lake. The seeds of the herbs and shrubs which have adhered to his smoking flanks, are washed off again by the waters. The thorny spray is torn off, and fixes itself in his hairy coat, until brushed off again in other thickets and copses. Even on the spot where the victim is devoured many of the seeds which he had swallowed immediately before the chase may be left on the ground uninjured, and ready to spring up in a new soil.

The passage, indeed, of undigested seeds through the stomachs of animals is one of the most efficient causes of the dissemination of plants, and is of all others, perhaps, the most likely to be overlooked. Few are ignorant that a portion of the oats eaten by a horse preserve their germinating faculty in the dung. The fact of their being still nutritious is not lost on the sagacious rook. To many, says Linnaeus, it seems extraordinary, and something of a prodigy, that when a field is well tilled and sown with the best wheat, it frequently produces darnel or the wild oat, especially if it be manured with new dung: they do not consider that the fertility of the smaller seeds is not destroyed in the stomachs of animals.*

Agency of birds. — Some birds of the order Passeres devour the seeds of plants in great quantities, which

* Linnæus, Amœn. Acad., vol. ii. p. 409.

they eject again in very distant places, without destroying its faculty of vegetation ; thus a flight of larks will fill the cleanest field with a great quantity of various kinds of plants, as the melilot trefoil (*Medicago lupulina*), and others whose seeds are so heavy that the wind is not able to scatter them to any distance.* In like manner, the blackbird and misselthrush, when they devour berries in too great quantities, are known to consign them to the earth undigested in their excrement.†

Pulpy fruits serve quadrupeds and birds as food, while their seeds, often hard and indigestible, pass uninjured through the intestines, and are deposited far from their original place of growth in a condition peculiarly fit for vegetation.‡ So well are the farmers, in some parts of England, aware of this fact, that when they desire to raise a quickset edge in the shortest possible time, they feed turkeys with the haws of the common white-thorn (*Crataegus Oxyacantha*), and then sow the stones which are ejected in their excrement, whereby they gain an entire year in the growth of the plant.§ Birds when they pluck cherries, sloes, and haws, fly away with them to some convenient place ; and when they have devoured the fruit, drop the stone into the ground. Captain Cook, in his account of the volcanic island of Tanna, one of the New Hebrides, which he visited in his second voyage, makes the following interesting observation : — “ Mr. Forster, in his botanical excursion this day, shot a pigeon, in the craw

* Amœn. Acad., vol. iv. Essay 75. § 8.

† Ibid., vol. vi. § 22.

‡ Smith’s Introd. to Phys. and Syst. Botany, p. 304. 1807.

§ This information was communicated to me by Professor Henslow, of Cambridge.

of which was a wild nutmeg. He took some pains to find the tree on this island, but his endeavours were without success."* It is easy, therefore, to perceive, that birds in their migrations to great distances, and even across seas, may transport seeds to new isles and continents.

The sudden deaths to which great numbers of frugivorous birds are annually exposed must not be omitted as auxiliary to the transportation of seeds to new habitations. When the sea retires from the shore, and leaves fruits and seeds on the beach, or in the mud of estuaries, it might, by the returning tide, wash them away again, or destroy them by long immersion; but when they are gathered by land birds which frequent the sea-side, or by waders and water-fowl, they are often borne inland; and if the bird to whose crop they have been consigned is killed, they may be left to grow up far from the sea. Let such an accident happen but once in a century, or a thousand years, it will be sufficient to spread many of the plants from one continent to another; for in estimating the activity of these causes, we must not consider whether they act slowly in relation to the period of our observation, but in reference to the duration of species in general.

Let us trace the operation of this cause in connexion with others. A tempestuous wind bears the seeds of a plant many miles through the air, and then delivers them to the ocean; the oceanic current drifts them to a distant continent; by the fall of the tide they become the food of numerous birds, and one of these is seized by a hawk or eagle, which, soaring across hill and dale to a place of retreat, leaves, after devouring its prey,

* Book iii. ch. iv.

the unpalatable seeds to spring up and flourish in a new soil.

The machinery before adverted to is so capable of disseminating seeds over almost unbounded spaces; that were we more intimately acquainted with the economy of nature, we might probably explain all the instances which occur of the aberration of plants to great distances from their native countries. The real difficulty which must present itself to every one who contemplates the present geographical distribution of species, is the small number of exceptions to the rule of the non-intermixture of different groups of plants. Why have they not, supposing them to have been ever so distinct originally, become more blended and confounded together in the lapse of ages?

Agency of man in the dispersion of plants. — But in addition to all the agents already enumerated as instrumental in diffusing plants over the globe, we have still to consider man — one of the most important of all. He transports with him, into every region, the vegetables which he cultivates for his wants; and is the involuntary means of spreading a still greater number which are useless to him, or even noxious. “When the introduction of cultivated plants,” says De Candolle, “is of recent date, there is no difficulty in tracing their origin; but when it is of high antiquity, we are often ignorant of the true country of the plants on which we feed. No one contests the American origin of the maize or the potato; nor the origin, in the Old World, of the coffee-tree, and of wheat. But there are certain objects of culture, of very ancient date, between the tropics, such, for example, as the banana, of which the origin cannot be verified. Armies, in modern times, have been known to carry, in all

directions, grain and cultivated vegetables from one extremity of Europe to the other; and thus have shown us how, in more ancient times, the conquests of Alexander, the distant expeditions of the Romans, and afterwards the crusades, may have transported many plants from one part of the world to the other.”*

But, besides the plants used in agriculture, the number which have been naturalized by accident, or which man has spread unintentionally, is considerable. One of our old authors, Josselyn, gives a catalogue of such plants as had, in his time, sprung up in the colony since the English planted and kept cattle in New England. They were two-and-twenty in number. The common nettle was the first which the settlers noticed; and the plantain was called by the Indians “Englishman’s foot,” as if it sprung from their footsteps. †

“ We have introduced every where,” observes De Candolle, “ some weeds which grow among our various kinds of wheat, and which have been received, perhaps, originally from Asia along with them. Thus, together with the Barbary wheat, the inhabitants of the south of Europe have sown, for many ages, the plants of Algiers and Tunis. With the wools and cottons of the East, or of Barbary, there are often brought into France the grains of exotic plants, some of which naturalize themselves. Of this I will cite a striking example. There is, at the gate of Montpellier, a meadow set apart for drying foreign wool *after it has been washed*. There hardly passes a year without foreign plants being found naturalized in this drying-ground: I have gathered there *Centaurea parviflora*, *Psoralea palæstina*, and

* De Candolle, *Essai Elémen.*, &c., p. 50.

† *Quarterly Review*, vol. xxx. p. 8.

Hypericum crispum." This fact is not only illustrative of the aid which man lends inadvertently to the propagation of plants, but it also demonstrates the multiplicity of seeds which are borne about in the woolly and hairy coats of wild animals.

The same botanist mentions instances of plants naturalized in seaports by the ballast of ships; and several examples of others which have spread through Europe from botanical gardens, so as to have become more common than many indigenous species.

It is scarcely a century, says Linnæus, since the Canadian erigeron, or flea-bane, was brought from America to the botanical garden at Paris: and already the seeds have been carried by the winds, so that it is diffused over France, the British islands, Italy, Sicily, Holland, and Germany.* Several others are mentioned by the Swedish naturalist, as having been dispersed by similar means. The common thorn-apple (*Datura Stramonium*), observes Willdenow, now grows as a noxious weed throughout all Europe, with the exception of Sweden, Lapland, and Russia. It came from the East Indies and Abyssinia to us, and was so universally spread by certain quacks, who used its seed as an emetic. †

In hot and ill-cultivated countries, such naturalizations take place more easily. Thus the *Chenopodium ambrosioides*, sown by Mr. Burchell on a point of St. Helena, multiplied so in four years as to become one of the commonest weeds in the island. ‡

The most remarkable proof, says De Candolle, of

* *Essay on the Habitable Earth, Amœn. Acad.*, vol. ii. p. 409.

† *Principles of Botany*, p. 389.

‡ *Ibid.*

the extent to which man is unconsciously the instrument of dispersing and naturalizing species, is found in the fact, that in New Holland, America, and the Cape of Good Hope, the aboriginal European species exceed in number all the others which have come from any distant regions ; so that, in this instance, the influence of man has surpassed that of all the other causes which tend to disseminate plants to remote districts.

Although we are but slightly acquainted, as yet, with the extent of our instrumentality in naturalizing species, yet the facts ascertained afford no small reason to suspect, that the number which we introduce unintentionally exceeds all those transported by design. Nor is it unnatural to suppose that the functions, which the inferior beings, extirpated by man, once discharged in the economy of nature, should devolve upon the human race. If we drive many birds of passage from different countries, we are probably required to fulfil their office of carrying seeds, eggs of fish, insects, mollusks, and other creatures, to distant regions ; if we extirpate quadrupeds, we must replace them, not merely as consumers of the animal and vegetable substances which they devoured, but as disseminators of plants, and of the inferior classes of the animal kingdom. I do not mean to insinuate that the very same changes which man brings about would have taken place by means of the agency of other species, but merely that he supersedes a certain number of agents ; and so far as he disperses plants unintentionally, or against his will, his intervention is strictly analogous to that of the species so extirpated.

I may observe, moreover, that if, at former periods,

the animals inhabiting any given district have been partially altered by the extinction of some species, and the introduction of others, whether by new creations or by immigration, a change must have taken place in regard to the particular plants conveyed about with them to foreign countries. As, for example, when one set of migratory birds is substituted for another, the countries from and to which seeds are transported are immediately changed. Vicissitudes, therefore, analogous to those which man has occasioned, may have previously attended the springing up of new relations between species in the vegetable and animal worlds.

It may also be remarked, that if man is the most active agent in enlarging, so also is he in circumscribing the geographical boundaries of particular plants. He promotes the migration of some, he retards that of other species, so that, while in many respects he appears to be exerting his power to blend and confound the various provinces of indigenous species, he is, in other ways, instrumental in obstructing the fusion into one group of the inhabitants of contiguous provinces.

Thus, for example, when two botanical regions exist in the same great continent, such as *the European region*, comprehending the central parts of Europe and those surrounding the Mediterranean, and *the Oriental region*, as it has been termed, embracing the countries adjoining the Black Sea and the Caspian, the interposition between these of thousands of square miles of cultivated lands, opposes a new and powerful barrier against the mutual interchange of indigenous plants. Botanists are well aware that garden plants naturalize and diffuse themselves with great facility in compa-

ratively unreclaimed countries, but spread themselves slowly and with difficulty in districts highly cultivated. There are many obvious causes for this difference: by drainage and culture the natural variety of stations is diminished, and those stray individuals by which the passage of a species from one fit station to another is effected, are no sooner detected by the agriculturist, than they are uprooted as weeds. The larger shrubs and trees, in particular, can scarcely ever escape observation, when they have attained a certain size, and will rarely fail to be cut down if unprofitable.

The same observations are applicable to the interchange of the insects, birds, and quadrupeds of two regions situated like those above alluded to. No beasts of prey are permitted to make their way across the intervening arable tracts. Many birds, and hundreds of insects, which would have found some palatable food amongst the various herbs and trees of the primeval wilderness, are unable to subsist on the olive, the vine, the wheat, and a few trees and grasses favoured by man. In addition, therefore, to his direct intervention, man, in this case, operates indirectly to impede the dissemination of plants, by intercepting the migrations of animals, many of which would otherwise have been active in transporting seeds from one province to another.

Whether, in the vegetable kingdom, the influence of man will tend, after a considerable lapse of ages, to render the geographical range of *species in general* more extended, as De Candolle seems to anticipate, or whether the compensating agency above alluded to will not counterbalance the exceptions caused by our naturalizations, admits at least of some doubt. In the

attempt to form an estimate on this subject, we must be careful not to under-rate, or almost overlook, as some appear to have done, the influence of man in checking the diffusion of plants, and restricting their distribution to narrower limits.

CHAPTER VI.

**LAWS WHICH REGULATE THE GEOGRAPHICAL DISTRIBUTION
OF SPECIES — *continued.***

Geographical distribution of animals — Buffon on specific distinctness of quadrupeds of old and new world — Different regions of indigenous mammalia — Quadrupeds in islands — Range of the Cetacea — Dispersion of quadrupeds — their powers of swimming — Migratory instincts — Drifting of animals on ice-floes — On floating islands of drift-timber — Migrations of Cetacea — Habitations of birds — Their migrations and facilities of diffusion — Distribution of reptiles, and their powers of dissemination.

Geographical distribution of animals. — ALTHOUGH in speculating on “philosophical possibilities,” said Buffon, “the same temperature might have been expected, all other circumstances being equal, to produce the same beings in different parts of the globe, both in the animal and vegetable kingdoms, yet it is an undoubted fact, that when America was discovered, its indigenous quadrupeds were all dissimilar to those previously known in the Old World. The elephant, the rhinoceros, the hippopotamus, the cameleopard, the camel, the dromedary, the buffalo, the horse, the ass, the lion, the tiger, the apes, the baboons, and a number of other mammalia, were nowhere to be met with on the new continent; while in the old, the American species, of the same great class, were nowhere to be

seen — the tapir, the lama, the pecari, the jaguar, the couguar, the agouti, the paca, the coati, and the sloth."

These phenomena, although few in number relatively to the whole animate creation, were so striking and so positive in their nature, that the great French naturalist caught sight at once of a general law in the geographical distribution of organic beings, namely, the limitation of groups of distinct species to regions separated from the rest of the globe by certain natural barriers. It was, therefore, in a truly philosophical spirit that, relying on the clearness of the evidence obtained respecting the larger quadrupeds, he ventured to call in question the identifications announced by some contemporary naturalists of species of animals said to be common to the southern extremities of America and Africa.*

Causes which prevent the migration of animals. — The migration of quadrupeds from one part of the globe to another, observes one of our ablest writers, is prevented by uncongenial climates and the branches of the ocean which intersect continents. "Hence, by a reference to the geographical site of countries, we may divide the earth into a certain number of regions fitted to become the abodes of particular groups of animals, and we shall find, on inquiry, that each of these provinces, thus conjecturally marked out, is actually inhabited by a distinct nation of quadrupeds."†

Where the continents of the Old and New World

* Buffon, vol. v. — On the Virginian Opossum.

† Prichard's Phys. Hist. of Mankind, vol. i. p. 54. In some of the preliminary chapters will be found a sketch of the leading facts illustrative of the geographical distribution of animals, drawn up with the author's usual clearness and ability.

approximate to each other towards the north, the narrow straits which separate them are frozen over in winter, and the distance is further lessened by intervening islands. Thus a passage from one continent to another becomes practicable to such quadrupeds as are fitted to endure the intense cold of the arctic circle. Accordingly, the whole arctic region has become one of the provinces of the animal kingdom, and contains many species common to both the great continents. But the temperate regions of America, which are separated by a wide extent of ocean from those of Europe and Asia, contain each a distinct nation of indigenous quadrupeds. There are three groups of *tropical* mammalia belonging severally to America, Africa, and continental India, each inhabiting lands separated from each other by the ocean.

In Peru and Chili, says Humboldt, the region of the grasses, which is at an elevation of from 12,300 to 15,400 feet, is inhabited by crowds of lama, guanaco, and alpaca. These quadrupeds, which here represent the genus camel of the ancient continent, have not extended themselves either to Brazil or Mexico; because, during their journey, they must necessarily have descended into regions that were too hot for them.*

Marsupial quadrupeds in New Holland.—New Holland is well known to contain a most singular and characteristic assemblage of mammiferous animals, consisting of more than forty species of the marsupial family, or those furnished with a pouch under the belly for their young, of which scarcely any congeners occur elsewhere, except a few species in some islands of the

* Description of the Equatorial Regions.

Indian archipelago and the opossums of America. There are, it appears, some examples of marsupial animals in the eastern hemisphere out of the Australian continent, as for instance, in New Ireland, New Guinea, and the Moluccas.

This almost exclusive occupation of the Australian continent by the kangaroos and other tribes of pouched animals, although it has justly excited great attention, is a fact, nevertheless, in strict accordance with the general laws of the distribution of species; since, in other parts of the globe, we find peculiarities of form, structure, and habit, in birds, reptiles, insects, or plants, confined entirely to one hemisphere, or one continent, and sometimes to much narrower limits.

In the south of Africa. — The southern region of Africa, where that continent extends into the temperate zone, constitutes another separate zoological province, surrounded as it is on three sides by the ocean, and cut off from the countries of milder climate, in the northern hemisphere, by the intervening torrid zone. In many instances, this region contains the same genera which are found in temperate climates to the northward of the line: but then the southern are different from the northern species. Thus, in the south we find the quagga and the zebra; in the north, the horse, the ass, and the *jiggetai* of Asia.

The south of Africa is spread out into fine level plains from the tropic to the Cape. In this region, says Pennant, besides the horse genus, of which five species have been found, there are also peculiar species of rhinoceros, the hog, and the hyrax, among pachydermatous races; and amongst the ruminating, the giraffe, the Cape buffalo, and a variety of remarkable antelopes,

as the springbok, the oryx, the gnou, the leucophoë, the pygarga, and several others.*

In the Indian archipelago. — The Indian archipelago presents peculiar phenomena in regard to its indigenous mammalia, which, in their generic character, recede, in some respects, from that of the animals of the Indian continent, and approximate to the African. The Sunda isles contain a hippopotamus, which is wanting in the rivers of Asia; Sumatra, a peculiar species of tapir, and a rhinoceros resembling the African more than the Indian species, but specifically distinguishable from both. †

Beyond the Indian archipelago is an extensive region, including New Guinea, New Britain, and New Ireland, together with the archipelago of Solomon's Islands, the New Hebrides, and Louisiade, and the more remote group of islands in the great southern ocean, which may be considered as forming one zoological province. Although these remarkable countries are extremely fertile in their vegetable productions, they are almost wholly destitute of native warm-blooded quadrupeds, except a few species of bats, and some domesticated animals in the possession of the natives. ‡

Quadrupeds in islands. — Quadrupeds found on islands situated near the continents generally form a part of the stock of animals belonging to the adjacent mainland; but islands remote from continents, especially those of small size, are either destitute of quadrupeds, except such as have been conveyed to them

* Pennant's Hist. of Quadrupeds, cited by Prichard, Phys. Hist. of Mankind, vol. i. p. 66.

† Prichard, ibid.; Cuvier, Ann. du Muséum, tom. vii.

‡ Prichard, ibid., p. 56.

by man, or contain species peculiar to them. In the Galapagos archipelago no indigenous quadrupeds were found except one mouse, which is supposed to be distinct from any hitherto found elsewhere. A peculiar species of fox is indigenous in the Falkland Islands, and a rat in New Zealand, which last country, notwithstanding its magnitude, is destitute of other mammalia, except bats, and these, says Dr. Prichard, may have made their way along the chain of islands which extend from the shores of New Guinea far into the Southern Pacific. The same author remarks, that among the various groups of fertile islands in the Pacific, no quadrupeds have been met with except the rat and a few bats as above mentioned, and the dog and hog, which appear to have been conveyed thither by the natives from New Guinea. "Rats are to be found even on some desert islands, whither they may have been conveyed by canoes which have occasionally approached the shore. It is known, also, that rats occasionally swim in large numbers to considerable distances." *

Geographical range of the cetacea. — It is natural to suppose that the geographical range of the different species of cetacea should be less correctly ascertained than that of the terrestrial mammifers. It is, however, well known that the whales which are obtained by our fishers in the South Seas are distinct from those of the North ; and the same dissimilarity has been found in all the other marine animals of the same class, so far as they have yet been studied by naturalists.

Dispersion of quadrupeds. — Let us now inquire what facilities the various land quadrupeds enjoy of spreading themselves over the surface of the earth.

* Prichard, Phys. Hist. of Mankind, vol. i, p. 75.

In the first place, as their numbers multiply, all of them, whether they feed on plants, or prey on other animals, are disposed to scatter themselves gradually over as wide an area as is accessible to them. But before they have extended their migrations over a large space, they are usually arrested either by the sea, or a zone of uncongenial climate, or some lofty and unbroken chain of mountains, or a tract already occupied by a hostile and more powerful species.

Their powers of swimming. — Rivers and narrow friths can seldom interfere with their progress ; for the greater part of them swim well, and few are without this power when urged by danger and pressing want. Thus, amongst beasts of prey, the tiger is seen swimming about among the islands and creeks in the delta of the Ganges, and the jaguar traverses with ease the largest streams in South America.* The bear, also, and the bison, cross the current of the Mississippi. The popular error, that the common swine cannot escape by swimming when thrown into the water, has been contradicted by several curious and well-authenticated instances during the recent floods in Scotland. One pig, only six months old, after having been carried down from Garmouth to the bar at the mouth of the Spey, a distance of a quarter of a mile, swam four miles eastward to Port Gordon, and landed safe. Three others, of the same age and litter, swam, at the same time, five miles to the west, and landed at Blackhill. †

In an adult and wild state, these animals would doubtless have been more strong and active, and

* Buffon, vol. v. p. 204.

† Sir T. D. Lauder, Bart., on the Floods in Morayshire, Aug. 1829, p. 302. second edition.

might, when hard pressed, have performed a much longer voyage. Hence islands remote from the continent may obtain inhabitants by casualties which, like the late storms in Morayshire, may only occur once in many centuries, or thousands of years, under all the same circumstances. It is obvious that powerful tides, winds, and currents, may sometimes carry along quadrupeds capable, in like manner, of preserving themselves for hours in the sea, to very considerable distances ; and in this way, perhaps, the tapir (*Tapir Indicus*) may have become common to Sumatra and the Malayan peninsula.

To the elephant, in particular, the power of crossing rivers is essential in a wild state, for the quantity of food which a herd of these animals consumes renders it necessary that they should be constantly moving from place to place. The elephant crosses the stream in two ways. If the bed of the river be hard, and the water not of too great a depth, he fords it. But when he crosses great rivers, such as the Ganges and the Niger, the elephant swims deep, so deep, that the end of his trunk only is out of the water ; for it is a matter of indifference to him whether his body be completely immersed, provided he can bring the tip of his trunk to the surface, so as to breathe the external air.

Animals of the deer kind frequently take to the water, especially in the rutting season, when the stags are seen swimming for several leagues at a time, from island to island, in search of the does, especially in the Canadian lakes ; and in some countries where there are islands near the sea shore, they fearlessly enter the sea and swim to them. In hunting excursions, in

North America, the elk of that country is frequently pursued for great distances through the water.

The large herbivorous animals, which are gregarious, can never remain long in a confined region, as they consume so much vegetable food. The immense herds of bisons (*Bos Americanus*) which often, in the great valleys of the Mississippi and its tributaries, blacken the surface of the prairie lands, are continually shifting their quarters, followed by wolves, which prowl about in their rear. "It is no exaggeration," says Mr. James, "to assert, that in one place, on the banks of the Platte, at least ten thousand bisons burst on our sight in an instant. In the morning, we again sought the living picture; but upon all the plain, which last evening was so teeming with noble animals, not one remained." *

Migratory instincts.—Besides the disposition common to the individuals of every species slowly to extend their range in search of food, in proportion as their numbers augment, a migratory instinct often develops itself in an extraordinary manner, when, after an unusually prolific season, or upon a sudden scarcity of provisions, great multitudes are threatened by famine. It may be useful to enumerate some examples of these migrations, because they may put us upon our guard against attributing a high antiquity to a particular species merely because it is diffused over a great space: they show clearly how soon, in a state of nature, a newly created species might spread itself, in every direction, from a single point.

In very severe winters, great numbers of the black

* Expedition from Pittsburg to the Rocky Mountains, vol. ii.
p. 153.

bears of America migrate from Canada into the United States; but in milder seasons, when they have been well fed, they remain and hibernate in the north.* The reindeer which, in Scandinavia, can scarcely exist to the south of the sixty-fifth parallel, descends, in consequence of the greater coldness of the climate, to the fiftieth degree, in Chinese Tartary, and often roves into a country of more southern latitude than any part of England.

In Lapland, and other high latitudes, the common squirrels, whenever they are compelled, by want of provisions, to quit their usual abodes, migrate in amazing numbers, and travel directly forwards, allowing neither rocks and forests, nor the broadest waters, to turn them from their course. Great numbers are often drowned in attempting to pass friths and rivers. In like manner the small Norway rat sometimes pursues its migrations in a straight line across rivers and lakes; and Pennant informs us, that when the rats, in Kamtschatka, become too numerous, they gather together in the spring, and proceed in great bodies westward, swimming over rivers, lakes, and arms of the sea. Many are drowned or destroyed by water-fowl or fish. As soon as they have crossed the river Penginsk, at the head of the gulf of the same name, they turn southward, and reach the rivers Judoma and Okotsk by the middle of July; a district more than 800 miles distant from their point of departure.

The lemings, also, a small kind of rat, are described as natives of the mountains of Kolen, in Lapland; and once or twice in a quarter of a century they appear in vast numbers, advancing along the ground, and “ de-

* Richardson's Fauna Boreali-Americana, p. 16.

vouring every green thing." Innumerable bands march from the Kolen, through Nordland and Finmark, to

Fig. 74.

The Lemming, or Lapland Marmot (*Mus Lemmus, Linn.*).

the Western Ocean, which they immediately enter; and, after swimming about for some time, perish. Other bands take their route through Swedish Lapland, to the Bothnian Gulf, where they are drowned in the same manner. They are followed in their journeys by bears, wolves, and foxes, which prey upon them incessantly. They generally move in lines, which are about three feet from each other, and exactly parallel, going directly forward through rivers and lakes; and when they meet with stacks of hay or corn, gnawing their way through them instead of passing round.* These excursions usually precede a rigorous winter, of which the lemmings seem in some way forewarned.

Vast troops of the wild ass, or *onager* of the ancients, which inhabit the mountainous deserts of Great Tartary, feed, during the summer, in the tracts east and north of Lake Aral. In the autumn they collect in herds of hundreds, and even thousands, and direct their course towards the north of India, and often to Persia, to enjoy a warm retreat during winter.† Bands

* Phil. Trans. vol. ii. p. 872.

† Wood's Zoography, vol. i. p. 11.

of two or three hundred quaggas, a species of wild ass, are sometimes seen to migrate from the tropical plains of southern Africa to the vicinity of the Malaleeven river. During their migrations they are followed by lions, who slaughter them night by night.*

The migratory swarms of the springbok, or Cape antelope, afford another illustration of the rapidity with which a species under certain circumstances may be diffused over a continent. When the stagnant pools of the immense deserts south of the Orange River dry up, which often happens after intervals of three or four years, myriads of these animals desert the parched soil, and pour down like a deluge on the cultivated regions near the Cape. The havoc committed by them resembles that of the African locusts; and so crowded are the herds, that “the lion has been seen to walk in the midst of the compressed phalanx with only as much room between him and his victims as the fears of those immediately around could procure by pressing outwards.”†

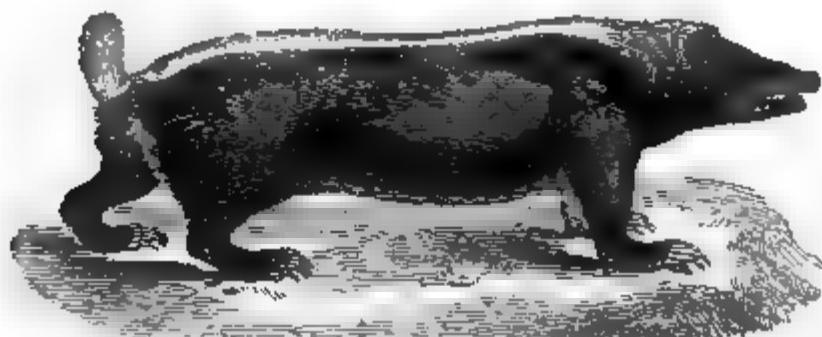
Dr. Horsfield mentions a singular fact in regard to the geographical distribution of the *Mydaus meliceps*, an animal intermediate between the polecat and badger. It inhabits Java, and is “confined exclusively to those mountains which have an elevation of more than seven thousand feet above the level of the ocean; on these it occurs with the same regularity as many plants. The long-extended surface of Java, abounding with conical points which exceed this elevation, affords

* On the authority of Mr. Campbell. Library of Entert. Know., Menageries, vol. i. p. 152.

† Cuvier's Animal Kingdom by Griffiths, vol. ii. p. 109. Library of Entert. Know., Menageries, vol. i. p. 866.

many places favourable for its resort. On ascending these mountains, the traveller scarcely fails to meet with this animal, which, from its peculiarities, is universally known to the inhabitants of these elevated

Fig. 75.



Mydaus meliceps, or badger-headed *Mydaus*. Length, including the tail, 18 inches.

tracts, while to those of the plains it is as strange as an animal from a foreign country. In my visits to the mountainous districts, I uniformly met with it; and, as far as the information of the natives can be relied on, it is found on all the mountains." *

Now, if asked to conjecture how the *Mydaus* arrived at the elevated regions of each of these isolated mountains, we might say that, before the island was peopled by man, by whom their numbers are now thinned, they may occasionally have multiplied so as to be forced to collect together and migrate: in which case, notwithstanding the slowness of their motions, some few would succeed in reaching another mountain, some twenty, or even, perhaps, fifty miles distant; for although the climate of the hot intervening plains would be unfavourable to them, they might support it for a time, and would find there abundance of insects

* Horsfield, *Zoological Researches in Java*, No. ii., from which the figure is taken.

on which they feed. Volcanic eruptions, which, at different times, have covered the summits of some of those lofty cones with sterile sand and ashes, may have occasionally contributed to force on these migrations.

Drifting of animals on ice-floes—The power of the terrestrial mammalia to cross the sea is very limited, and it was before stated that the same species is scarcely ever common to districts widely separated by the ocean. If there be some exceptions to this rule, they generally admit of explanation; for there are natural means whereby some animals may be floated across the water, and the sea sometimes wears a passage through a neck of land, leaving individuals of a species on each side of the new channel. Polar bears are known to have been frequently drifted on the ice from Greenland to Iceland: they can also swim to considerable distances, for Captain Parry, on the return of his ships through Barrow's Strait, met with a bear swimming in the water about midway between the shores, which were about forty miles apart, and where no ice was in sight.* “Near the east coast of Greenland,” observes Scoresby, “they have been seen on the ice in such quantities, that they were compared to flocks of sheep on a common; and they are often found on field-ice, above two hundred miles from the shore.”† Wolves, in the arctic regions, often venture upon the ice near the shore, for the purpose of preying upon young seals, which they surprise when asleep. When these ice-floes get detached, the wolves are often carried out to sea; and though some may be drifted to islands or continents, the greater part of

* Append. to Parry's Second Voyage, years 1819–20.

† Account of the Arctic Regions, vol. i. p. 513.

them perish, and have been often heard in this situation howling dreadfully, as they die by famine. *

During the short summer which visits Melville Island, various plants push forth their leaves and flowers the moment the snow is off the ground, and form a carpet spangled with the most lively colours. These secluded spots are reached annually by herds of musk-oxen and reindeer, which travel immense distances over dreary and desolate regions, to graze undisturbed on these luxuriant pastures.† The reindeer often pass along in the same manner, by the chain of the Aleutian Islands, from Behring's Straits to Kamtschatka, subsisting on the moss found in these islands during their passage.‡ But the musk-ox, notwithstanding its migratory habits, and its long journeys over the ice, does not exist either in Asia or Greenland. §

On floating islands of drift-wood. — Within the tropics there are no ice-floes ; but, as if to compensate for that mode of transportation, there are floating islets of matted trees, which are often borne along through considerable spaces. These are sometimes seen sailing at the distance of fifty or one hundred miles from the mouth of the Ganges, with living trees standing erect upon them. The Amazon, the Congo, and the Orinoco, also produce these verdant rafts, which are formed in the manner already described when speaking of the great raft of the Atchafalaya, an arm of the Mississippi, where a natural bridge of timber, ten miles long, and more than two hundred yards wide, existed for more than forty years, supporting a luxuriant vege-

* Turton, in a note to Goldsmith's Nat. Hist., vol. iii. p. 43.

† Supplement to Parry's First Voyage of Disc., p. 189.

‡ Godman's American Nat. Hist., vol. i. p. 22.

§ Dr. Richardson, Brit. Assoc. Reports, vol. v. p. 161.

tation, and rising and sinking with the water which flowed beneath it.

On these green islets of the Mississippi, observes Malte-Brun, young trees take root, and the pistia and acanthus display their yellow flowers: there serpents, birds, and the cayman alligator, come to repose, and all are sometimes carried to the sea, and engulfed in its waters.*

Spix and Martius relate that, during their travels in Brazil, they were exposed to great danger while ascending the Amazon in a canoe, from the vast quantity of drift-wood constantly propelled against them by the current; so much so, that their safety depended on the crew being always on the alert to turn aside the trunks of trees with long poles. The tops alone of some trees appeared above water, others had their roots attached to them with so much soil that they might be compared to floating islets. On these, say the travellers, we saw some very singular assemblages of animals, pursuing peacefully their uncertain way in strange companionship. On one raft were several grave-looking storks, perched by the side of a party of monkeys, who made comical gestures, and burst into loud cries, on seeing the canoe. On another was seen a number of ducks and divers, sitting by a group of squirrels. Next came down, upon the stem of a large rotten cedar-tree, an enormous crocodile, by the side of a tiger-cat, both animals regarding each other with hostility and mistrust, but the saurian being evidently most at his ease, as conscious of his superior strength.†

* System of Geography, vol. v. p. 157.

† Spix and Martius, Reise, &c., vol. iii. pp. 1011. 1013.

Similar green rafts, principally composed of canes and brushwood, are called "camelotes" on the Parana in South America; and they are occasionally carried down by inundations, bearing on them the tiger, cayman, squirrels, and other quadrupeds, which are said to be always terror-stricken on their floating habitation. No less than four tigers (pumas) were landed in this manner in one night at Monte Video, lat. 35° S., to the great alarm of the inhabitants, who found them prowling about the streets in the morning.*

In a memoir lately published, a naval officer relates that, as he returned from China by the eastern passage he fell in, among the Moluccas, with several small floating islands of this kind, covered with mangrove-trees interwoven with underwood. The trees and shrubs retained their verdure, receiving nourishment from a stratum of soil which formed a white beach round the margin of each raft, where it was exposed to the washing of the waves and the rays of the sun.† The occurrence of soil in such situations may easily be explained; for all the natural bridges of timber which occasionally connect the islands of the Ganges, Mississippi, and other rivers, with their banks, are exposed to floods of water, densely charged with sediment.

Captain W. H. Smyth informs me, that, when cruising in the Cornwallis amidst the Philippine Islands, he has more than once seen, after those dreadful hur-

* Sir W. Parish's Buenos Ayres, p. 187., and Robertson's Letters on Paraguay, p. 220.

† United Service Journal, No. xxiv. p. 697.

ricanes called typhoons, floating masses of wood, with trees growing upon them ; and ships have sometimes been in imminent peril, as often as these islands were mistaken for terra firma, when, in fact, they were in rapid motion.

It is highly interesting to trace, in imagination, the effects of the passage of these rafts from the mouth of a large river to some archipelago, such as those in the South Pacific, raised from the deep, in comparatively modern times, by the operations of the volcano and the earthquake, and the joint labours of coral animals and testacea. If a storm arise, and the frail vessel be wrecked, still many a bird and insect may succeed in gaining, by flight, some island of the newly formed group, while the seeds and berries of herbs and shrubs, which fall into the waves, may be thrown upon the strand. But if the surface of the deep be calm, and the rafts are carried along by a current, or wafted by some slight breath of air fanning the foliage of the green trees, it may arrive, after a passage of several weeks, at the bay of an island, into which its plants and animals may be poured out as from an ark, and thus a colony of several hundred new species may at once be naturalized.

The reader should be reminded, that I merely advert to the transportation of these rafts as of extremely rare and accidental occurrence ; but it may account, in tropical countries, for some of the rare exceptions to the general law of the confined range of species.

Migrations of the cetacea.—Many of the cetacea, the whales of the northern seas for example, are found to desert one tract of the sea, and to visit another very distant, when they are urged by want of food, or danger. The seals also retire from the coast of Greenland

in July, return again in September, and depart again in March, to return in June. They proceed in great droves northwards, directing their course where the sea is most free from ice, and are observed to be extremely fat when they set out on this expedition, and very lean when they come home again.*

Species of the Mediterranean, Black Sea, and Caspian identical. — Some naturalists have wondered that the sea calves, dolphins, and other marine mammalia of the Mediterranean and Black Sea, should be identical with those found in the Caspian : and among other fanciful theories, they have suggested that they may dive through subterranean conduits, and thus pass from one sea into the other. But as the occurrence of wolves and other noxious animals, on both sides of the British Channel, was adduced, by Verstegan and Desmarest, as one of many arguments to prove that England and France were once united ; so the correspondence of the aquatic species of the inland seas of Asia with those of the Black Sea tends to confirm the hypothesis, for which there are abundance of independent geological data, that those seas were connected together by straits at no remote period of the earth's history.

Geographical Distribution and Migrations of Birds.

I shall now offer a few observations on some of the other divisions of the animal kingdom. Birds, notwithstanding their great locomotive powers, form no exception to the general rules already laid down ; but, in this class, as in plants and terrestrial quadrupeds,

* Krantz, vol. i. p. 129., cited by Goldsmith, Nat. Hist., vol. iii. p. 260.

different groups of species are circumscribed within definite limits. We find, for example, one assemblage in the Brazils, another in the same latitudes in Central Africa, another in India, and a fourth in New Holland. Of twenty-six different species of land birds found in the Galapagos archipelago, all, with the exception of one, are distinct from those inhabiting other parts of the globe*; and in other archipelagos a single island sometimes contains a species found in no other spot on the whole earth; as is exemplified in some of the parrot tribes. In this extensive family, which are, with few exceptions, inhabitants of tropical regions, the American group has not one in common with the African, nor either of these with the parrots of India.†

Another illustration is afforded by that minute and beautiful tribe, the humming birds. The whole of them are, in the first place, peculiar to the new world; but some species are confined to Mexico, while others exist only in some of the West India Islands, and have not been found elsewhere in the western hemisphere. Yet there are species of this family which have a vast range, as the *Trochilus flammifrons* (or *Mellisuga Kingii*), which is found over a space of 2500 miles on the west coast of South America, from the hot dry country of Lima to the humid forests of Terra del Fuego. Captain King, during his survey in the years 1826—30, found this bird at the Straits of Magellan, in the month of May—the depth of winter—sucking the flowers of a large species of fuchsia, then in bloom, in the midst of a shower of snow.

The ornithology of our own country affords one well-known and striking exemplification of the law of a limited specific range; for the common grouse (*Tetrao*

* Darwin's Journal, &c., p. 461.

† Prichard, vol. i. p. 47.

scoticus) occurs nowhere in the known world except in the British isles.

Some species of the vulture tribe are said to be true cosmopolites ; and the common wild goose (*Anas anser*, Linn.), if we may believe some ornithologists, is a general inhabitant of the globe, being met with from Lapland to the Cape of Good Hope, frequent in Arabia, Persia, China, and Japan, and in the American continent, from Hudson's Bay to South Carolina.* An extraordinary range has also been attributed to the nightingale, which extends from western Europe to Persia, and still farther. In a work entitled Specchio Comparativo†, by Charles Bonaparte, many species of birds are enumerated as common to Rome and Philadelphia ; the greater part of these are migratory, but some of them, such as the long-eared owl (*Strix otus*), are permanent in both countries. The correspondence of the ornithological fauna of the eastern and western hemispheres increases considerably, as might have been anticipated in high northern latitudes.‡

Their facilities of diffusion. — In parallel zones of the northern and southern hemispheres, a great general correspondence of form is observable, both in the aquatic and terrestrial birds ; but there is rarely any specific identity : and this phenomenon is truly remarkable, when we recollect the readiness with which some birds, not gifted with great powers of flight, shift their quarters to different regions, and the facility with which others, possessing great strength of wing, perform their aërial voyage. Some migrate periodically from high latitudes, to avoid the cold of winter,

* Bewick's Birds, vol. ii. p. 294., who cites Latham.

† Pisa, 1827 (not sold).

‡ Bachman, Silliman's Amer. Journ., No 61. p. 92.

and the accompaniments of cold, — scarcity of insects and vegetable food; others, it is said, for some particular kinds of nutriment required for rearing their young: for this purpose, they often traverse the ocean for thousands of miles, and recross it at other periods, with equal security.

Periodical migrations, no less regular, are mentioned by Humboldt, of many American water-fowl, from one part of the tropics to another in a zone where there is the same temperature throughout the year. Immense flights of ducks leave the valley of the Orinoco, when the increasing depth of its waters and the flooding of its shores prevent them from catching fish, insects, and aquatic worms. They then betake themselves to the Rio Negro and Amazon, having passed from the eighth and third degrees of north latitude to the first and fourth of south latitude, directing their course south-south-east. In September, when the Orinoco decreases and re-enters into its channel, these birds return northwards.*

The insectivorous swallows which visit our island would perish during winter, if they did not annually repair to warmer climes. It is supposed that, in these aerial excursions the average rapidity of their flight is not less than fifty miles an hour; so that, when aided by the wind, they soon reach warmer latitudes. Spallanzani calculated that the swallow can fly at the rate of ninety-two miles an hour, and conceived that the rapidity of the swift might be three times greater.† The rate of flight of the eider duck (*Anas mollissima*) is said to be ninety miles an hour; and Bachman says

* *Voyage aux Régions Equinoxiales*, tome vii. p. 429.

† *Fleming, Phil. Zool.*, vol. ii. p. 43.

that the hawk, wild pigeon (*Columba migratoria*), and several species of wild ducks, in North America, fly at the rate of forty miles an hour, or nearly a thousand miles in twenty-four hours.*

When we reflect how easily different species, in a great lapse of ages, may be each overtaken by gales and hurricanes, and, abandoning themselves to the tempest, be scattered at random through various regions of the earth's surface, where the temperature of the atmosphere, the vegetation, and the animal productions, might be suited to their wants, we shall be prepared to find some species capriciously distributed, and to be sometimes unable to determine the native countries of each. Captain Smyth informs me, that, when engaged in his survey of the Mediterranean, he encountered a gale in the Gulf of Lyons, at the distance of between twenty and thirty leagues from the coast of France, which bore along many land birds of various species, some of which alighted on the ship, while others were thrown with violence against the sails. In this manner islands become tenanted by species of birds inhabiting the nearest mainland.

Geographical Distribution and Dissemination of Reptiles.

A few facts respecting the third great class of vertebrated animals will suffice to show that the plan of nature in regard to their location on the globe is perfectly analogous to that already exemplified in other parts of the organic creation, and has probably been determined by similar causes.

* Silliman's Amer. Journ., No. 61. p. 83.

Habitations of reptiles. — Of the great saurians, the gavials which inhabit the Ganges differ from the cayman of America, or the crocodile of the Nile. The monitor of New Holland is specifically distinct from the Indian species ; these latter, again, from the African, and all from their congeners in the new world. So in regard to snakes ; we find the boa of America represented by the python, a different though nearly allied genus in India. America is the country of the rattle-snake ; Africa, of the cerastes ; and Asia, of the hooded snake, or cobra di capello. The amphibious genera *Siren* and *Menopoma* belong to North America, possessing both lungs and gills, and respiring at pleasure either air or water. The only analogous animal of the old world is the *Proteus anguinus* of the lakes of Lower Carniola, and the grotto of Adelsberg between Trieste and Vienna.*

There is a legend that St. Patrick expelled all reptiles from Ireland ; and certain it is that none of the three species of snakes common in England, nor the toad, have been observed there by naturalists. They have our common frog, and our water-newt, and according to Ray (Quad. 264.), the green lizard (*Lacerta viridis*).

Migrations of the larger reptiles. — The range of the large reptiles is, in general, quite as limited as that of some orders of the terrestrial mammalia. The great saurians sometimes cross a considerable tract in order to pass from one river to another ; but their motions by land are generally slower than those of quadrupeds. By water, however, they may transport themselves to distant situations more easily. The larger alligator of

* Richardson, Brit. Assoc. Rep., vol. v. p. 202.

the Ganges sometimes descends beyond the brackish water of the delta into the sea; and in such cases it might chance to be drifted away by a current, and survive till it reached a shore at some distance; but such casualties are probably very rare.

Turtles migrate in large droves from one part of the ocean to another during the ovipositing season; and they find their way annually to the island of Ascension, from which the nearest land is about 800 miles distant. Dr. Fleming mentions, that an individual of the hawk's bill turtle (*Chelonia imbricata*), so common in the American seas, has been taken at Papa Stour, one of the West Zetland islands*; and, according to Sibbald, "the same animal came into Orkney." Another was taken, in 1774, in the Severn, according to Turton. Two instances, also, of the occurrence of the leatherne tortoise (*C. coriacea*), on the coast of Cornwall, in 1756, are mentioned by Borlase. These animals of more southern seas can be considered only as stragglers attracted to our shores during uncommonly warm seasons by an abundant supply of food, or carried by the gulf stream, or driven by storms to high latitudes.

Some of the smaller reptiles lay their eggs on aquatic plants; and these must often be borne rapidly by rivers, and conveyed to distant regions in a manner similar to the dispersion of seeds before adverted to. But that the larger ophidians may be themselves transported across the seas, is evident from the following most interesting account of the arrival of one at the island of St. Vincent. It is worthy of being recorded, says Mr. Guilding, "that a noble specimen of the *Boa constrictor* was lately conveyed to us by the currents,

* Brit. Animals, p. 149., who cites Sibbald.

twisted round the trunk of a large sound cedar tree, which had probably been washed out of the bank by the floods of some great South American river, while its huge folds hung on the branches, as it waited for its prey. The monster was fortunately destroyed after killing a few sheep, and his skeleton now hangs before me in my study, putting me in mind how much reason I might have had to fear in my future rambles through the forests of St. Vincent, had this formidable reptile been a pregnant female, and escaped to a safe retreat."*

* Zool. Journ. vol. iii. p. 406. Dec. 1827.

CHAPTER VII.

LAWS WHICH REGULATE THE GEOGRAPHICAL DISTRIBUTION OF SPECIES — *continued.*

Geographical distribution and migrations of fish — of testacea — of zoophytes — Distribution of insects — Migratory instincts of some species — Certain types characterize particular countries — Their means of dissemination — Geographical distribution and diffusion of man — Speculations as to the birth-place of the human species — Progress of human population — Drifting of canoes to vast distances — On the involuntary influence of man in extending the range of many other species.

Geographical Distribution and Migrations of Fish.

ALTHOUGH we are less acquainted with the habitations of marine animals than with the grouping of the terrestrial species before described, yet it is well ascertained that their distribution is governed by the same general laws. The testimony borne by MM. Péron and Lesueur to this important fact is remarkably strong. These eminent naturalists, after collecting and describing many thousand species of marine animals which they brought to Europe from the southern hemisphere, insist most emphatically on their distinctness from those north of the equator; and this remark they extend to animals of all classes, from those of a more simple to those of a more complex organization — from the sponges and medusæ to the cetacea. "Among all those which we have been able to examine," say

they, "with our own eyes, or with regard to which it has appeared to us possible to pronounce with certainty, there is not a single animal of the southern regions which is not distinguished by essential characters from the analogous species in the northern seas."*

On comparing the fresh-water fish of Europe and North America, Dr. Richardson remarks, that the only species which is unequivocally common to the two continents is the pike (*Esox lucius*) ; and it is curious that this fish is unknown to the westward of the Rocky Mountains, the very coast which approaches nearest to the old continent.†

The fish of the Arabian Gulf are said to differ entirely from those of the Mediterranean, notwithstanding the proximity of these seas. The flying-fish are found (some stragglers excepted) only between the tropics ; in receding from the line, they never approach a higher latitude than the fortieth parallel. Those inhabiting the Atlantic are said to be different species from those of the eastern ocean.‡ The electric gymnotus belongs exclusively to America ; the trembler, or *Silurus electricus*, to the rivers of Africa ; but the torpedo, or cramp-fish, is said to be dispersed over all tropical, and many temperate seas. §

All are aware that there are certain fish of passage which have their periodical migrations, like some tribes of birds. The salmon, towards the season of spawning, ascends the rivers for hundreds of miles, leaping up the cataracts which it meets in its course, and then retreats again into the depths of the ocean. The her-

* Sur les Habitations des Animaux Marins. — Ann. du Mus., tom. xv. cited by Prichard, Phys. Hist. of Mankind, vol. i. p. 51.

† Brit. Assoc. Reports, vol. v. p. 203.

‡ Malte-Brun, vol. i. p. 507.

§ Ibid.

ring and the haddock, after frequenting certain shores, in vast shoals, for a series of years, desert them again, and resort to other stations, followed by the species which prey on them. Eels are said to descend into the sea for the purpose of producing their young, which are seen returning into the fresh water by myriads, extremely small in size, but possessing the power of surmounting every obstacle which occurs in the course of a river, by applying their slimy and glutinous bodies to the surface of rocks, or the gates of a lock, even when dry, and so climbing over it.* Before the year 1800 there were no eels in Lake Wener, the largest inland lake in Sweden, which discharges its waters by the celebrated cataracts of Trolhättan. But I am informed by Professor Nilsson that since the canal was opened uniting the river Gotha with the lake by a series of nine locks, each of great height, eels have been observed in abundance in the lake. It appears, therefore, that though they were unable to ascend the falls, they have made their way by the locks, by which in a very short space a difference of level of 114 feet is overcome.

Gmelin says, that the anseres (wild geese, ducks, and others) subsist, in their migrations, on the spawn of fish ; and that oftentimes, when they void the spawn, two or three days afterwards, the eggs retain their vitality unimpaired.† When there are many disconnected fresh-water lakes in a mountainous region, at various elevations, each remote from the other, it has often been deemed inconceivable how they could all become stocked with fish from one common source ; but it has been suggested, that the minute eggs of

* Phil. Trans. 1747, p. 395. † Amer. Acad., Essay 75.

these animals may sometimes be entangled in the feathers of water-fowl. These, when they alight to wash and plume themselves in the water, may often unconsciously contribute to propagate swarms of fish, which, in due season, will supply them with food. Some of the water-beetles, also, as the dyticidæ, are amphibious, and in the evening quit their lakes and pools ; and, flying in the air, transport the minute ova of fishes to distant waters. In this manner some naturalists account for the fry of fish appearing occasionally in small pools caused by heavy rains ; but the showers of small fish, stated in so many accounts to have fallen from the atmosphere, require further investigation.

Geographical Distribution and Migrations of Testacea.

The testacea, of which so great a variety of species occurs in the sea, are a class of animals of peculiar importance to the geologist ; because their remains are found in strata of all ages, and generally in a higher state of preservation than those of other organic beings. Climate has a decided influence on the geographical distribution of species in this class ; but as there is much greater uniformity of temperature in the waters of the ocean, than in the atmosphere which invests the land, the diffusion of many marine mollusks is extensive.

Causes which limit the extension of many species. — Some forms attain their fullest development in warm latitudes ; and are often exclusively confined to the torrid zone, as *Nautilus*, *Harpa*, *Terebellum*, *Pyramidella*, *Delphinula*, *Aspergillum*, *Tridacna*, *Cucullaea*,

Crassatella, Corbis, Perna, and Plicatula. Other forms are limited to one region of the sea, as the *Trigonia* to parts of Australia, and the *Concholepas* to the western coast of South America, where the shells differ almost entirely from those on the eastern coast of the same continent. Such being the case, it is not wonderful that we find an entire difference between the South American shells and those of the Indian archipelago in the same latitude. On the shores of many of the islands of the South Pacific peculiar species have been obtained. Péron and Lesueur remark, that the *Haliotis gigantea* of Van Diemen's Land, and the *Phasianella*, diminish in size as they follow the coasts of New Holland, northwards to King George's Sound, and entirely disappear beyond them.* But we are as yet by no means able to sketch out the submarine provinces of shells, as the botanist has done those of the terrestrial, and even of the subaqueous plants. There can be little doubt, however, that the boundaries in this case, both of latitude and longitude, will be found in general well defined. The continuous lines of continents, stretching from north to south, prevent a particular species from belting the globe, and following the direction of the isothermal lines. The inhabitants of the West Indian seas, for example, cannot enter the Pacific, without passing round through the inclement climate of Cape Horn. Currents also flowing permanently in certain directions, and the influx at certain points of great bodies of fresh water, limit the extension of many species. Those which love deep water are arrested by shoals; others, fitted for shallow seas, cannot migrate across unfathomable abysses.

* Ann. du Mus. d'Hist. Nat. tom. xv.

Great range of some species. — Some few species, however, have an immense range, as the *Sanguinolaria rugosa*, Lamk., which is found in the West Indies, Brazil, the Red Sea, Tranquebar, the Chinese sea, and in the island of Annaa, one of the South Sea islands, where it was discovered by Mr. Cuming.* The *Cypræa moneta*, a Mediterranean shell, occurs also in South Africa, the Isle of France, the East Indies, in China, the South Sea, and even as far west as Otaheite. The *Turbo petræus* inhabits the seas of England, Guadalupe, and the Cape of Good Hope.†

The *Ianthina fragilis* has wandered into almost every sea, both tropical and temperate. This "common oceanic snail" derives its buoyancy from an admirably contrived float, which has enabled it not only to disperse itself so universally, but to become an active agent in disseminating other species, which attach themselves, or their ova, to its shell. ‡

It is evident that, among the testacea, as in plants and the higher order of animals, there are species which have a power of enduring a wide range of temperature, whereas others cannot resist a considerable change of climate. Among the fresh-water mollusks, and those which breathe air, Féruccac mentions a few instances of species of almost universal diffusion.

The *Helix putris* (*Succinea putris*, Lam.), so com-

* On the authority of Dr. Beck.

† Fé. art. Géogr. Phys. Dict. Class. d'Hist. Nat.

‡ Mr. Broderip possesses specimens of *Ianthina fragilis*, bearing more than one species of barnacle (*Pentelasmis*), presented to him by Captain King and Lieutenant Graves. One of these specimens, taken alive by Captain King far at sea, and a little north of the equator, is so loaded with those cirripeds, and with numerous ova, that all the upper part of its shell is invisible.

mon in Europe, where it reaches from Norway to Italy, is also found in Egypt, in the United States, in Newfoundland, Jamaica, Tranquebar, and, it is even said, in the Marianne Isles. As this animal inhabits constantly the borders of pools and streams where there is much moisture, it is not impossible that different water-fowl have been the agents of spreading some of its minute eggs, which may have been entangled in their feathers. *Helix aspersa*, one of the commonest of our larger land-shells, is found in South America, at the foot of Chimborazo, as also in Cayenne, and in St. Helena. Some conchologists have conjectured that it was accidentally imported in some ship; for it is an eatable species, and these animals are capable of retaining life during long voyages, without air or nourishment.*

Confined range of others. — Mr. Lowe, in a memoir published in the Cambridge Transactions in 1831, enumerates seventy-one species of land mollusca, collected by him in the islands of Madeira and Porto Santo, sixty of which belonged to the genus *Helix* alone, including as sub-genera *Bulimus* and *Achatina*, and excluding *Vitrina* and *Clausilia*; — forty-four of these are new. It is remarkable, that very few of the above-mentioned

* Four individuals of a large species of land-shell (*Bulimus*), from Valparaiso, were brought to England by Lieutenant Graves, who accompanied Captain King in his late expedition to the Straits of Magellan. They had been packed up in a box, and enveloped in cotton: two for a space of thirteen, one for seventeen, and a fourth for upwards of twenty months; but, on being exposed by Mr. Broderip to the warmth of a fire in London, and provided with tepid water and leaves, they revived, and lived for several months in Mr. Loddiges' palm-house, till accidentally drowned.

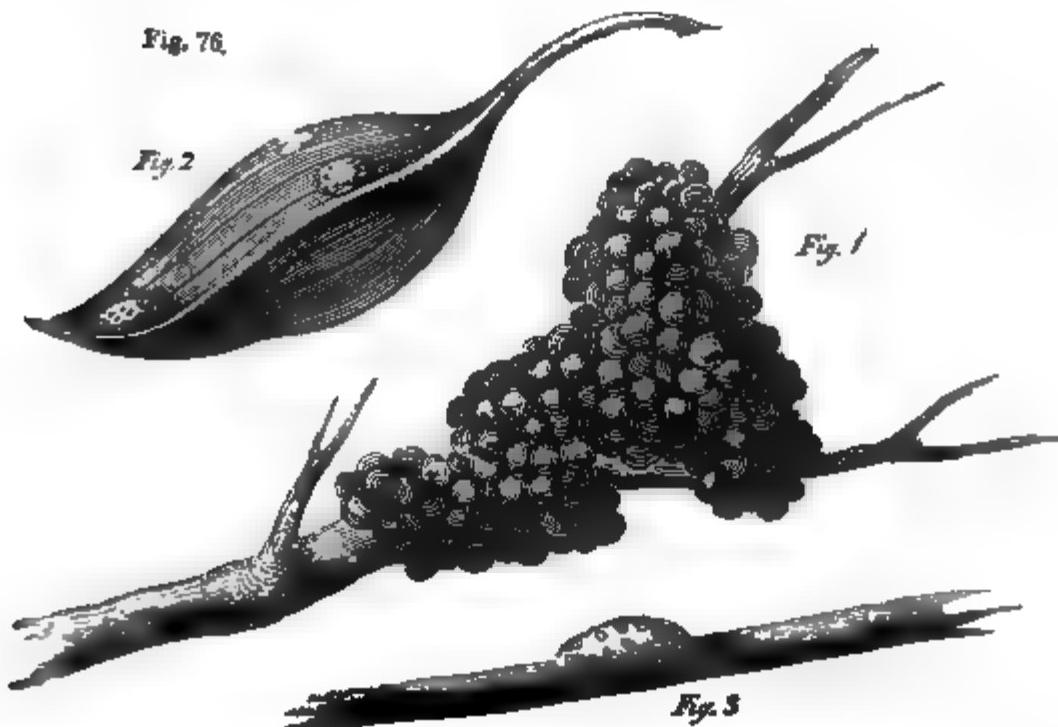
species are common to the neighbouring archipelago of the Canaries; but it is a still more striking fact, that, of the sixty species of the three genera above-mentioned, thirty-one are natives of Porto Santo; whereas, in Madeira, which contains ten times the superficies, were found but twenty-nine. Of these only four were common to the two islands, which are separated by a distance of only twelve leagues; and two even of these four (namely, *Helix rhodostoma* and *H. ventrosa*) are species of general diffusion, common to Madeira, the Canaries, and the South of Europe.*

The confined range of these mollusks may easily be explained, if we admit that species have only one birth-place; and the only problem to be solved would relate to the exceptions—to account for the dissemination of some species throughout several islands, and the European continent. May not the eggs, when washed into the sea by the undermining of cliffs, or blown by a storm from the land, float uninjured to a distant shore?

Their mode of diffusion. — Notwithstanding the proverbially slow motion of snails and mollusks in general, and although many aquatic species adhere constantly to the same rock for their whole lives, they are by no means destitute of provision for disseminating themselves rapidly over a wide area. Some lay their eggs in a sponge-like nidus, wherein the young remain enveloped for a time after their birth; and this buoyant substance floats far and wide as readily as sea-weed. The young of other viviparous tribes are often borne along, entangled in sea-weed. Sometimes they are so light, that, like grains of sand, they can be

* Camb. Phil. Trans. vol. iv. 1831.

easily moved by currents. Balani and serpulæ are sometimes found adhering to floating cocoa-nuts, and even to fragments of pumice. In rivers and lakes, on



Eggs of fresh-water Mollusks.

Fig. 1. Eggs of *Ampullaria ovata* (a fluvial species), fixed to a small sprig which had fallen into the water.

Fig. 2. Eggs of *Pionorbis albus*, attached to a dead leaf lying under water.

Fig. 3. Eggs of the common Limneæ (*L. vulgaris*), adhering to a dead stick under water.

the other hand, aquatic univalves usually attach their eggs to leaves and sticks which have fallen into the water, and which are liable to be swept away during floods, from tributaries to the main streams, and from thence to all parts of the same basins. Particular species may thus migrate during one season from the head waters of the Mississippi, or any other great river, to countries bordering the sea, at the distance of many thousand miles.

An illustration of the mode of attachment of these eggs will be seen in the annexed cut. (Fig. 76.)

The habit of some testacea to adhere to floating wood is proved by their fixing themselves to the bottoms of ships. By this mode of conveyance *Mytilus polymorphus*, previously known only in the Danube and Wolga, may have been brought to the Commercial Docks in the Thames, and to Hamburg, where the species is now domiciled. But Mr. Gray suggests that as the animal is known to have the faculty of living for a very long time out of water, it is more probable that it was brought in Russian timber than borne uninjured through the salt-water at the bottom of a vessel.*

A lobster (*Astacus marinus*) was lately taken alive covered with living mussels (*Mytilus edulis*)†; and a large female crab (*Cancer pagurus*), covered with oysters, and bearing also *Anomia ephippium*, and actiniæ, was taken in April, 1832, off the English coast. The oysters, seven in number, include individuals of six years' growth, and the two largest are four inches long and three inches and a half broad. Both the crab and the oysters were seen alive by Mr. Robert Brown.‡

From this example we learn the manner in which

* Phil. Trans. 1835, p. 303.

† The specimen is preserved in the Museum of the Zool. Soc. of London.

‡ This specimen is in the collection of my friend Mr. Broderip, who observes, that this crab, which was apparently in perfect health, could not have cast her shell for six years, whereas some naturalists have stated that the species moults annually, without limiting the moulting period to the early stages of growth of the animal.

oysters may be diffused over every part of the sea where the crab wanders; and if they are at length carried to a spot where there is nothing but fine mud, the foundation of a new oyster-bank may be laid on the death of the crab. In this instance the oysters survived the crab many days, and were killed at last only by long exposure to the air.

Geographical Distribution and Migrations of Zoophytes..

Zoophytes are very imperfectly known, but there can be little doubt that each maritime region possesses species peculiar to itself. The madrepores, or lamelliferous polyparia, are found in their fullest development only in the tropical seas of Polynesia and the East and West Indies; and this family is represented only by a few species in our seas. Those even of the Mediterranean are inferior in size; and, for the most part, different from such as inhabit the tropics. Péron and Lesueur, after studying the Holothuriæ, Medusæ, and other congeners of delicate and changeable forms, came to the conclusion that each kind has its place of residence determined by the temperature necessary to support its existence. Thus, for example, they found the abode of *Pyrosoma Atlantica* to be confined to one particular region of the Atlantic Ocean.*

Let us now inquire how the transportation of polyps from one part of the globe to another is effected. Many of them, as in the families Flustra and Sertularia, attach themselves to sea-weed, and are occasionally drifted along with it. Many fix themselves to the shells of mollusca, and are thus borne along by

* *Voy. aux Terres Australes*, tome i. p. 492.

them to short distances. Some polyps, like some species of sea-pens, float about in the ocean, and are usually believed to possess powers of spontaneous motion. But the most frequent mode of transportation consists in the buoyancy of their eggs, or certain small vesicles, which are detached, and are capable of becoming the foundation of a new colony. These gems, as they are called, have, in many instances, a locomotive power of their own, by which they proceed in a determinate direction for several days after separation from the parent. They are propelled by means of numerous short threads or *ciliæ*, which are in constant and rapid vibration; and, when thus supported in the water, they may be borne along by currents to a great distance.

That some zoophytes adhere to floating bodies, is proved by their being found attached to the bottoms of ships, like certain testacea before alluded to.

Geographical Distribution and Migrations of Insects.

Before I conclude this sketch of the manner in which the habitable parts of the earth are shared out among particular assemblages of organic beings, I must offer a few remarks on insects, which, by their numbers and the variety of their powers and instincts, exert a prodigious influence in the economy of animate nature. As a large portion of these minute creatures are strictly dependent for their subsistence on certain species of vegetables, the entomological provinces must coincide in a considerable degree with the botanical.

All the insects, says Latreille, brought from the eastern parts of Asia and China, whatever be their

latitude and temperature, are distinct from those of Europe and of Africa. The insects of the United States, although often they approach very close to our own, are nevertheless specifically distinguishable by some characters. In South America, the equinoctial lands of New Granada and Peru on the one side, and of Guiana on the other, contain for the most part distinct groups; the Andes forming the division, and interposing a narrow line of severe cold between climates otherwise very similar.*

Migratory instincts.—The insects of the United States, even those of the northern provinces as far as Canada, differ specifically from the European; while those of Greenland appear to be in a great measure identical with our own. Some insects are very local; while a few, on the contrary, are common to remote countries, between which the torrid zone and the ocean intervene. Thus our painted lady butterfly (*Vanessa cardui*) re-appears at the Cape of Good Hope and in New Holland and Japan with scarcely a varying streak.† The same species is said to be one of the few insects which are universally dispersed over the earth, being found in Europe, Asia, Africa, and America; and its wide range is the more interesting, because it seems explained by its migratory instinct, seconded, no doubt, by a capacity, enjoyed by few species, of enduring a great diversity of temperature.

A vast swarm of this species, forming a column from ten to fifteen feet broad, was, a few years since, observed in the Canton de Vaud; they traversed the

* *Géographie Générale des Insectes et des Arachnides.* Mém. du Mus. d' Hist. Nat. tome iii.

† Kirby and Spence, vol. iv. p. 487. ; and other authors.

country with great rapidity from north to south, all flying onwards in regular order, close together, and not turning from their course on the approach of other objects. Professor Bonelli, of Turin, observed in March of the same year, a similar swarm of the same species, also directing their flight from north to south, in Piedmont, in such immense numbers that at night the flowers were literally covered with them. They had been traced from Coni, Raconi, Susa, &c. A similar flight at the end of the last century is recorded by M. Louch, in the Memoirs of the Academy of Turin. The fact is the more worthy of notice, because the caterpillars of this butterfly are not gregarious, but solitary from the moment that they are hatched; and this instinct remains dormant, while generation after generation passes away, till it suddenly displays itself in full energy when their numbers happen to be in excess.

Not only peculiar species, but certain types, distinguish particular countries; and there are groups, observes Kirby, which represent each other in distant regions, whether in their form, their functions, or in both. Thus the honey and wax of Europe, Asia, and Africa, are in each case prepared by bees congeneric with our common hive-bee (*Apis*, Latr.); while, in America, this genus is nowhere indigenous, but is replaced by *Melipona*, *Trigona*, and *Euglossa*; and in New Holland by a still different, but undescribed type.* The European bee (*Apis mellifica*), although not a native of the new world, is now established, both in North and South America. It was introduced into the United States by some of the early settlers, and

* Kirby and Spence, vol. iv. p. 497.

has since overspread the vast forests of the interior, building hives in the decayed trunks of trees. "The Indians," says Irving, "consider them as the harbinger of the white man as the buffalo is of the red man, and say that in proportion as the bee advances the Indian and the buffalo retire. It is said," continues the same writer, "that the wild bee is seldom to be met with at any great distance from the frontier, and that they have always been the heralds of civilization, preceding it as it advanced from the Atlantic borders. Some of the ancient settlers of the west even pretend to give the very year when the honey-bee first crossed the Mississippi.*

As almost all insects are winged, they can readily spread themselves wherever their progress is not opposed by uncongenial climates, or by seas, mountains, and other physical impediments; and these barriers they can sometimes surmount by abandoning themselves to violent winds, which, as I before stated, when speaking of the dispersion of seeds (p. 98.), may in a few hours carry them to very considerable distances. On the Andes some sphinxes and flies have been observed by Humboldt, at the height of 19,180 feet above the sea, and which appeared to him to have been involuntarily carried into these regions by ascending currents of air.†

White mentions a remarkable shower of aphides which seem to have emigrated, with an east wind, from the great hop plantations of Kent and Sussex, and blackened the shrubs and vegetables where they alighted at Selborne, spreading at the same time in

* Washington Irving's Tour in the Prairies, ch. ix.

† Description of the Equatorial Regions — Malte-Brun, vol. v. p. 379.

great clouds all along the vale from Farnham to Alton. These aphides are sometimes accompanied by vast numbers of the common lady-bird (*Coccinella septempunctata*), which feed upon them.*

It is remarkable, says Kirby, that many of the insects which are occasionally observed to emigrate, as, for instance, the libellulæ, coccinellæ, carabi, cicadæ, &c. are not usually social insects; but seem to congregate, like swallows, merely for the purpose of emigration.† Here, therefore, we have an example of an instinct developing itself on certain rare emergencies, causing unsocial species to become gregarious, and to venture sometimes even to cross the ocean.

The armies of locusts which darken the air in Africa and traverse the globe from Turkey to our southern counties in England, are well known to all. When the western gales sweep over the Pampas, they bear along with them myriads of insects of various kinds. As a proof of the manner in which species may be thus diffused, I may mention that when the Creole frigate was lying in the outer roads off Buenos Ayres, in 1819, at the distance of six miles from the land, her decks and rigging were suddenly covered with thousands of flies and grains of sand. The sides of the vessel had just received a fresh coat of paint, to which the insects adhered in such numbers as to spot and disfigure the vessel, and to render it necessary partially to renew the paint.‡ Captain W. H. Smyth was obliged to repaint his vessel, the Adventure, in the Mediterranean, from the same cause. He was on his way from Malta to Tripoli, when a southern wind

* Kirby and Spence, vol. ii. p. 9. 1817. † Ibid. p. 12.

‡ I am indebted to Lieutenant Graves, R. N., for this information.

blowing from the coast of Africa, then one hundred miles distant, drove such myriads of flies upon the fresh paint, that not the smallest point was left unoccupied by insects.

To the southward of the river Plate, off Cape St. Antonio, and at the distance of fifty miles from land, several large dragon-flies alighted on the Adventure frigate, during Captain King's late expedition to the Straits of Magellan. If the wind abates when insects are thus crossing the sea, the most delicate species are not necessarily drowned; for many can repose without sinking on the water. The slender long-legged tipulæ have been seen standing on the surface of the sea, when driven out far from our coast, and took wing immediately on being approached.* Exotic beetles are sometimes thrown on our shore, which revive after having been long drenched in salt water; and the periodical appearance of some conspicuous butterflies amongst us, after being unseen for five or fifty years, has been ascribed, not without probability, to the agency of the winds.

Inundations of rivers, observes Kirby, if they happen at any season except in the depth of winter, always carry down a number of insects, floating on the surface of bits of stick, weeds, &c.; so that when the waters subside, the entomologist may generally reap a plentiful harvest. In the dissemination, moreover, of these minute beings, as in that of plants, the larger animals play their part. Insects are, in numberless instances, borne along in the coats of animals, or the feathers of birds; and the eggs of some species are capable, like seeds, of resisting the digestive

* I state this fact on the authority of my friend, Mr. John Curtis.

powers of the stomach, and after they are swallowed with herbage, may be ejected again unharmed in the dung.

Geographical Distribution and Diffusion of Man.

I have reserved for the last some observations on the range and diffusion of the human species over the earth, and the influence of man in spreading other animals and plants, especially the terrestrial.

Many naturalists have amused themselves in speculating on the probable birth-place of mankind, the point from which, if we assume the whole human race to have descended from a single pair, the tide of emigration must originally have proceeded. It has been always a favourite conjecture, that this birth-place was situated within or near the tropics, where perpetual summer reigns, and where fruits, herbs, and roots are plentifully supplied throughout the year. The climate of these regions, it has been said, is suited to a being born without any covering, and who had not yet acquired the arts of building habitations or providing clothes.

Progress of human population. — “The hunter state,” it has been argued, “which Montesquieu placed the first, was probably only the second stage to which mankind arrived; since so many arts must have been invented to catch a salmon, or a deer, that society could no longer have been in its infancy when they came into use.”* When regions where the spontaneous fruits of the earth abound became overpeopled, men would naturally diffuse themselves over the neighbouring parts of the temperate zone; but a consider-

* Brand's Select Dissert. from the Amœn. Acad. vol. i. p. 118.

able time would probably elapse before this event took place ; and it is possible, as a writer before cited observes, that in the interval before the multiplication of their numbers and their increasing wants had compelled them to emigrate, some arts to take animals were invented, but far inferior to what we see practised at this day among savages. As their habitations gradually advanced into the temperate zone, the new difficulties they had to encounter would call forth by degrees the spirit of invention, and the probability of such inventions always rises with the number of people involved in the same necessity.*

A distinguished modern writer, who coincides for the most part in the views above mentioned, has introduced one of the persons in his second dialogue as objecting to the theory of the human race having gradually advanced from a savage to a civilized state, on the ground that “the first man must have inevitably been destroyed by the elements or devoured by savage beasts, so infinitely his superiors in physical force.”† He then contends against the difficulty here started by various arguments, all of which were, perhaps, superfluous ; for if a philosopher is pleased to indulge in conjectures on this subject, why should he not assign, as the original seat of man, some one of those large islands within the tropics, which are as free from large beasts of prey as Van Diemen’s Land or Australia ? Here man may have remained for a period, peculiar to a single island, just as some of the large anthropomorphous species are now limited to one island within the tropics. In such a situation, the new-born race might

* Brand’s Select Dissert. from the Amœn. Acad. vol. i. p.118.

† Sir H. Davy, Consolations in Travel, p. 74.

have lived in security, though far more helpless than the New Holland savages, and might have found abundance of vegetable food. Colonies may afterwards have been sent forth from this mother country, and then the peopling of the earth may have proceeded according to the hypothesis before alluded to.

In an early stage of society the necessity of hunting acts as a principle of repulsion, causing men to spread with the greatest rapidity over a country, until the whole is covered with scattered settlements. It has been calculated that eight hundred acres of hunting-ground produce only as much food as half an acre of arable land. When the game has been in a great measure exhausted, and a state of pasturage succeeds, the several hunter tribes, being already scattered, may multiply in a short time into the greatest number which the pastoral state is capable of sustaining. The necessity, says Brand, thus imposed upon the two savage states, of dispersing themselves far and wide over the country, affords a reason why, at a very early period, the worst parts of the earth may have become inhabited.

But this reason, it may be said, is only applicable in as far as regards the peopling of a continuous continent; whereas the smallest islands, however remote from continents, have almost always been found inhabited by man. St. Helena, it is true, afforded an exception; for when that island was discovered in 1501, it was only inhabited by sea-fowl, and occasionally by seals and turtles, and was covered with a forest of trees and shrubs, all of species peculiar to it, with one or two exceptions, and which seem to have been expressly created for this remote and insulated spot.*

* See p. 90.

The islands also of Mauritius, Bourbon, Pitcairns, and Juan Fernandez, and those of the Galapagos archipelago, one of which is seventy miles long, were uninhabited when first discovered, and what is more remarkable than all, the Falkland Islands, which together are 120 miles in length by 60 in breadth, and abounding in food fit for the support of man.

Drifting of canoes to vast distances. — But very few of the numerous coral islets and volcanos of the vast Pacific, capable of sustaining a few families of men, have been found untenanted; and we have, therefore, to inquire whence and by what means, if all the members of the great human family have had one common source, could those savages have migrated. Cook, Forster, and others, have remarked that parties of savages in their canoes must often have lost their way, and must have been driven on distant shores, where they were forced to remain, deprived both of the means and of the requisite intelligence for returning to their own country. Thus Captain Cook found on the island of Wateoo three inhabitants of Otaheite, who had been drifted thither in a canoe, although the distance between the two isles is 550 miles. In 1696, two canoes, containing thirty persons, who had left Ancorso, were thrown by contrary winds and storms on the island of Samar, one of the Philippines, at a distance of 800 miles. In 1721, two canoes, one of which contained twenty-four, and the other six persons, men, women, and children, were drifted from an island called Farroilep to the island of Guaham, one of the Marians, a distance of 200 miles.*

Kotzebue, when investigating the Coral Isles of

* Malte-Brun's Geography, vol. iii. p. 419.

Radack, at the eastern extremity of the Caroline Isles, became acquainted with a person of the name of Kadu, who was a native of Ulea, an isle 1500 miles distant, from which he had been drifted with a party. Kadu and three of his countrymen one day left Ulea in a sailing boat, when a violent storm arose, and drove them out of their course; they drifted about the open sea for eight months, according to their reckoning by the moon, making a knot on a cord at every new moon. Being expert fishermen, they subsisted entirely on the produce of the sea; and when the rain fell, laid in as much fresh water as they had vessels to contain it. "Kadu," says Kotzebue, "who was the best diver, frequently went down to the bottom of the sea, where it is well known that the water is not so salt, with a cocoa-nut shell, with only a small opening."* When these unfortunate men reached the isles of Radack, every hope and almost every feeling had died within them; their sail had long been destroyed, their canoe had long been the sport of winds and waves, and they were picked up by the inhabitants of Aur in a state of insensibility; but by the hospitable care of those islanders they soon recovered, and were restored to perfect health.†

Captain Beechey, in his late voyage to the Pacific, fell in with some natives of the Coral Islands, who had in a similar manner been carried to a great distance from their native country. They had embarked, to the

* Chamisso states that the water which they brought up was cooler, and, *in their opinion*, less salt. It is difficult to conceive its being fresher near the bottom, except where submarine springs may happen to rise.

† Kotzebue's *Voyage, 1815—1818.* Quarterly Review, vol. xxvi p. 361.

number of 150 souls, in three double canoes, from Anaa, or Chain Island, situated about three hundred miles to the eastward of Otaheite. They were overtaken by the monsoon, which dispersed the canoes; and after driving them about the ocean, left them becalmed, so that a great number of persons perished. Two of the canoes were never heard of, but the other was drifted from one uninhabited island to another, at each of which the voyagers obtained a few provisions; and at length, after having wandered for a distance of 600 miles, they were found and carried to their home in the Blossom.*

Mr. Crawfurd informs me that there are several well authenticated accounts of canoes having been drifted from Sumatra to Madagascar, and by such causes a portion of the Malayan language, with some useful plants, have been transferred to that island, which is principally peopled by negroes.

The space traversed in some of these instances was so great, that similar accidents might suffice to transport canoes from various parts of Africa to the shores of South America, or from Spain to the Azores, and thence to North America; so that man, even in a rude state of society, is liable to be scattered involuntarily by the winds and waves over the globe, in a manner singularly analogous to that in which many plants and animals are diffused. We ought not, then to wonder, that during the ages required for some tribes of the human race to attain that advanced stage of civilization which empowers the navigator to cross the ocean in all directions with security, the whole earth should have

* Narrative of a Voyage to the Pacific, &c., in the years 1825, 1826, 1827, 1828, p. 170.

become the abode of rude tribes of hunters and fishers. Were the whole of mankind now cut off, with the exception of one family, inhabiting the old or new continent, or Australia, or even some coral islet of the Pacific, we might expect their descendants, though they should never become more enlightened than the South Sea Islanders or the Esquimaux, to spread in the course of ages over the whole earth, diffused partly by the tendency of population to increase, in a limited district, beyond the means of subsistence, and partly by the accidental drifting of canoes by tides and currents to distant shores.

Involuntary Influence of Man in diffusing Animals and Plants.

Many of the general remarks which have been made respecting the influence of man in spreading or in checking the diffusion of plants, apply equally to his relations with the animal kingdom. On a future occasion, I shall be led to speak of the instrumentality of our species in naturalizing useful animals and plants in new regions, when explaining my views of the effects which the spreading and increase of certain species exert in the extirpation of others. At present I shall confine myself to a few remarks on the involuntary aid which man lends to the dissemination of species.

In the mammiferous class our influence is chiefly displayed in increasing the number of quadrupeds which are serviceable to us, and in exterminating or reducing the number of those which are noxious.

Sometimes, however, we unintentionally promote the multiplication of inimical species, as when we introduced the rat, which was not indigenous in the new

world, into all parts of America. They have been conveyed over in ships, and now infest a great multitude of islands and parts of that continent. In like manner the Norway rat has been imported into England, where it plunders our property in ships and houses.

Among birds, the house sparrow may be cited as a species known to have extended its range with the tillage of the soil. During the last century it has spread gradually over Asiatic Russia towards the north and east, always following the progress of cultivation. It made its first appearance on the Irtisch in Tobolsk, soon after the Russians had ploughed the land. It came in 1735 up the Obi to Beresow, and four years after to Naryn, about fifteen degrees of longitude farther east. In 1710, it had been seen in the higher parts of the coast of the Lena, in the government of Irkutzk. In all these places it is now common, but is not yet found in the uncultivated regions of Kamtschatka.*

The great viper (*Fer de lance*), a species no less venomous than the rattle-snake, which now ravages Martinique and St. Lucia, was accidentally introduced by man, and exists in no other part of the West Indies.

Many parasitic insects which attack our persons, and some of which are supposed to be peculiar to our species, have been carried into all parts of the earth, and have as high a claim as man to an *universal geographical distribution*.

* Gloger, Abänd. der Vögel, p. 103. ; Pallas, Zoog. Ross-Asiat. tom. ii. p. 197.

A great variety of insects have been transported in ships from one country to another, especially in warmer latitudes. Notwithstanding the coldness of our climate, we have been unable to prevent the cockroach (*Blatta orientalis*) from entering and diffusing itself in our ovens and kneading troughs, and availing itself of the artificial warmth which we afford. It is well known also that beetles, and many other kinds of ligniperdous insects, have been introduced into Great Britain in timber; especially several North American species. "The commercial relations," says Malte-Brun*, "between France and India, have transported from the latter country the *aphis*, which destroys the apple-tree, and two sorts of Neuroptera, the *lucifuga* and *flavicola*, mostly confined to Provence and the neighbourhood of Bourdeaux, where they devour the timber in the houses and naval arsenals."

Among mollusks we may mention the *Teredo navalis*, which is a native of equatorial seas, but which, by adhering to the bottom of ships, was transported to Holland, where it has been most destructive to vessels and piles. The same species has also become naturalized in England, and other countries enjoying an extensive commerce. *Bulimus undatus*, a land species of considerable size, native of Jamaica and other West Indian islands, has been imported, adhering to tropical timber, into Liverpool; and, as I learn from Mr. Broderip, is now naturalized in the woods near that town.

In all these and innumerable other instances we may regard the involuntary agency of man as strictly

* Syst. of Geog. vol. viii. p. 169.

analogous to that of the inferior animals. Like them, we unconsciously contribute to extend or limit the geographical range and numbers of certain species, in obedience to general rules in the economy of nature, which are for the most part beyond our control.

CHAPTER VIII.

THEORIES RESPECTING THE ORIGINAL INTRODUCTION OF SPECIES.

Proposal of an hypothesis on this subject — Supposed centres or foci of creation — Why distinct provinces of animals and plants have not become more blended together — Brocchi's speculations on the loss of species — Stations of plants and animals — Causes on which they depend — Stations of plants, how affected by animals — Equilibrium in the number of species, how preserved — Peculiar efficacy of insects in this task — Rapidity with which certain insects multiply or decrease in numbers — Effect of omnivorous animals in preserving the equilibrium of species — Reciprocal influence of aquatic and terrestrial species on each other.

Theory of Linnaeus. — It would be superfluous to examine the various attempts which were made to explain the phenomena of the distribution of species alluded to in the preceding chapters, in the infancy of the sciences of botany, zoology, and physical geography. The theories or rather conjectures then indulged now stand refuted by a simple statement of facts; and if Linnaeus were living he would be the first to renounce the notions which he promulgated. For he imagined the habitable world to have been for a certain time limited to one small tract, the only portion of the earth's surface that was as yet laid bare by the subsidence of the primæval ocean. In this fertile spot he supposed the originals of all the species of plants

which exist on this globe to have been congregated, together with the first ancestors of all animals and of the human race. “In quâ commodè habitaverint animalia omnia, et vegetabilia lætè germinaverint.” In order to accommodate the various habitudes of so many creatures, and to provide a diversity of climate suited to their several natures, the tract in which the creation took place was supposed to have been situated in some warm region of the earth, but to have contained a lofty mountain range, on the heights and in the declivities of which were to be found all temperatures and every climate, from that of the torrid to that of the frozen zone.*

That there never was a universal ocean since the planet was inhabited, or, rather, since the oldest groups of strata yet known to contain organic remains were formed, is proved by the presence of terrestrial plants in all the older formations; and if this conclusion was not established, yet no geologist could deny that, since the first small portion of the earth was laid dry, there have been many entire changes in the species of plants and animals inhabiting the land.

But, without dwelling on the above and other refuted theories, let us inquire whether some hypothesis cannot be substituted as simple as that of Linnaeus, to which the phenomena now ascertained in regard to the distribution both of aquatic and terrestrial species may be referred. The following may, perhaps, be reconcileable with known facts: — Each species may have had its origin in a single pair, or individual, where an individual was sufficient, and species may

* *De terrâ habitabili incremento*; also Prichard, *Phys. Hist. of Mankind*, vol. i. p. 17., where the hypotheses of different naturalists are enumerated.

have been created in succession at such times and in such places as to enable them to multiply and endure for an appointed period, and occupy an appointed space on the globe.

In order to explain this theory, let us suppose every living thing to be destroyed in the western hemisphere, both on the land and in the ocean, and permission to be given to man to people this great desert, by transporting into it animals and plants from the eastern hemisphere, a strict prohibition being enforced against introducing two original stocks of the same species.

Now it is easy to show that the result of such a mode of colonizing would correspond exactly, so far as regards the grouping of animals and plants, with that now observed throughout the globe. In the first place, it would be necessary for naturalists, before they imported species into particular localities, to study attentively the climate and other physical conditions of each spot. It would be no less requisite to introduce the different species in succession, so that each plant and animal might have time and opportunity to multiply before the species destined to prey upon it was admitted. Many herbs and shrubs, for example, must spread far and wide before the sheep, the deer, and the goat could be allowed to enter, lest they should devour and annihilate the original stocks of many plants, and then perish themselves for want of food. The above-mentioned herbivorous animals in their turn must be permitted to make considerable progress before the entrance of the first pair of wolves or lions. Insects must be allowed to swarm before the swallow could be permitted to skim through the air, and feast on thousands at one repast.

It is evident that, however equally in this case our

original stocks were distributed over the whole surface of land and water, there would nevertheless arise distinct botanical and zoological provinces, for there are a great many natural barriers which oppose common obstacles to the advance of a variety of species. Thus, for example, almost all the animals and plants naturalized by us, towards the extremity of South America, would be unable to spread beyond a certain limit, towards the east, west, and south ; because they would be stopped by the ocean, and a few of them only would succeed in reaching the cooler latitudes of the northern hemisphere, because they would be incapable of bearing the heat of the tropics, through which they must pass. In the course of ages, undoubtedly, exceptions would arise, and some species might become common to the temperate and polar regions, or both sides of the equator ; for I have before shown that the powers of diffusion conferred on some classes are very great. But we might confidently predict that these exceptions would never become so numerous as to invalidate the general rule.

Some of the plants and animals transplanted by us to the coast of Chili or Peru would never be able to cross the Andes, so as to reach the Eastern plains ; nor, for a similar reason, would those first established in the Pampas, or the valleys of the Amazon and the Orinoco, ever arrive at the shores of the Pacific.

In the ocean an analogous state of things would prevail ; for there, also, climate would exert a great influence in limiting the range of species, and the land would stop the migrations of aquatic tribes as effectually as the sea arrests the dispersion of the terrestrial. As certain birds, insects, and the seeds of plants can never cross the direction of prevailing winds, so cur-

rents form natural barriers to the dissemination of many oceanic races. A line of shoals may be as impassable to deep-water species, as are the Alps and the Andes to plants and animals peculiar to plains; while deep abysses may prove insuperable obstacles to the migrations of the inhabitants of shallow waters.

Supposed centres, or foci, of creation. — It is worthy of observation, that one effect of the introduction of single pairs of each species must be the confined range of certain groups in spots, which, like small islands, or solitary inland lakes, have few means of interchanging their inhabitants with adjoining regions. Now this congregating in a small space, of many peculiar species, would give an appearance of *centres* or *foci* of creation, as they have been termed, as if there were favourite points where the creative energy has been in greater action than in others, and where the numbers of peculiar organic beings have consequently become more considerable.

I do not mean to call in question the soundness of the inferences of some botanists, as to the former existence of certain limited spots whence species of plants have been propagated, radiating, as it were, in all directions from a common centre. On the contrary, I conceive these phenomena to be the necessary consequences of the plan of nature before suggested, operating during the successive mutations of the surface, some of which the geologist can prove to have taken place subsequently to the period when many species now existing were created. In order to exemplify how this arrangement of plants may have been produced, let us imagine that, about three centuries before the discovery of St. Helena (itself of submarine volcanic origin), a multitude of new islands had been

thrown up in the surrounding sea, and that these had each become clothed with plants emigrating from St. Helena, in the same manner as the wild plants of Campania have diffused themselves over Monte Nuovo. Whenever the first botanist investigated the new archipelago, he would, in all probability, find a different assemblage of plants in each of the islands of recent formation ; but, in St. Helena itself, he would meet with individuals of every species belonging to all parts of the archipelago, and some, in addition, peculiar to itself, viz., those which had not been able to obtain a passage into any one of the surrounding new-formed lands. In this case, it might be truly said that the original island was the primitive focus, or centre, of a certain type of vegetation ; whereas, in the surrounding islands, there would be a smaller number of species, yet all belonging to the same group.

But this peculiar distribution of plants would not warrant the conclusion that, in the space occupied by St. Helena, there had been a greater exertion of creative power than in the spaces of equal area occupied by the new adjacent lands, because, within the period in which St. Helena had acquired its peculiar vegetation, each of the spots supposed to be subsequently converted into land may have been the birth-places of a great number of *marine* animals and plants, which may have had time to scatter themselves far and wide over the southern Atlantic.

Why distinct provinces not more blended. — Perhaps it may be objected to some parts of the foregoing train of reasoning, that during the lapse of past ages, especially during many partial revolutions of the globe of comparatively modern date, different zoological and botanical provinces ought to have become more con-

founded and blended together — that the distribution of species approaches too nearly to what might have been expected, if animals and plants had been introduced into the globe when its physical geography had already assumed the features which it now wears ; whereas we know that, in certain districts, considerable geographical changes have taken place since species identical with those now in being were created.

Brocchi's speculations on loss of species. — These, and many kindred topics cannot be fully discussed until we have considered, not merely the general laws which may regulate the first introduction of species, but those which may limit their *duration* on the earth. Brocchi, whose untimely death in Egypt is deplored by all who have the progress of geology at heart, has remarked, when hazarding some interesting conjectures respecting "the loss of species," that a modern naturalist had no small assurance, who declared "that individuals alone were capable of destruction, and that species were so perpetuated that nature could not annihilate them, so long as the planet lasted, or at least that nothing less than the shock of a comet, or some similar disaster, could put an end to their existence."* The Italian geologist, on the contrary, had satisfied himself, that many species of testacea, which formerly inhabited the Mediterranean, had become extinct, although a great number of others, which had been the contemporaries of those lost races, still survived. He came to the opinion, that about half the species which peopled the waters when the Subapennine strata were deposited had gone out of existence ; and in this inference he does not appear to have been far wrong.

* Necker, *Phytozool. Philosoph.* p. 21. Brocchi, *Conch. Foss. Subap.* tome i. p. 229.

But, instead of seeking a solution of this problem, like some other geologists of his time, in a violent and general catastrophe, Brocchi endeavoured to imagine some regular and constant law by which species might be made to disappear from the earth gradually and in succession. The death, he suggested, of a species might depend, like that of individuals, on certain peculiarities of constitution conferred upon them at their birth ; and as the longevity of the one depends on a certain force of vitality, which, after a period, grows weaker and weaker, so the duration of the other may be governed by the quantity of prolific power bestowed upon the species, which, after a season, may decline in energy, so that the fecundity and multiplication of individuals may be gradually lessened from century to century, “until that fatal term arrives when the embryo, incapable of extending and developing itself, abandons, almost at the instant of its formation, the slender principle of life by which it was scarcely animated, — and so all dies with it.”

Now we might coincide in opinion with the Italian naturalist, as to the gradual extinction of species one after another, by the operation of regular and constant causes, without admitting an inherent principle of deterioration in their physiological attributes. We might concede, “that many species are on the decline, and that the day is not far distant when they will cease to exist;” yet deem it consistent with what we know of the nature of organic beings, to believe that the last individuals of each species retain their prolific powers in their full intensity.

Brocchi has himself speculated on the share which a change of climate may have had in rendering the Mediterranean unfit for the habitation of certain tes-

tacea, which still continued to thrive in the Indian Ocean, and of others which were now only represented by analogous forms within the tropics. He must also have been aware that other extrinsic causes, such as the progress of human population, or the increase of some one of the inferior animals, might gradually lead to the extirpation of a particular species, although its fecundity might remain to the last unimpaired. If, therefore, amid the vicissitudes of the animate and inanimate world, there are known causes capable of bringing about the decline and extirpation of species, it became him thoroughly to investigate the full extent to which these might operate, before he speculated on any cause of so purely hypothetical a kind as “the diminution of the prolific virtue.”

If it could have been shown that some wild plant had insensibly dwindled away and died out, as sometimes happens to cultivated varieties propagated by cuttings, even though climate, soil, and every other circumstance should continue identically the same—if any animal had perished while the physical condition of the earth, and the number and force of its foes, with every other extrinsic cause, remained unaltered, then might we have some ground for suspecting that the infirmities of age creep on as naturally on species as upon individuals. But, in the absence of such observations, let us turn to another class of facts, and examine attentively the circumstances which determine the *stations* of particular animals and plants, and perhaps we shall discover, in the vicissitudes to which these stations are exposed, a cause fully adequate to explain the phenomena under consideration.

Stations of plants and animals.—Stations comprehend all the circumstances, whether relating to the

animate or inanimate world, which determine whether a given plant or animal can exist in a given place; so that if it be shown that stations can become essentially modified by the influence of known causes, it will follow that species, as well as individuals, are mortal.

Every naturalist is familiar with the fact, that although in a particular country, such as Great Britain, there may be more than three thousand species of plants, ten thousand insects, and a great variety in each of the other classes; yet there will not be more than a hundred, perhaps not half that number, inhabiting any given locality. There may be no want of space in the supposed tract: it may be a large mountain, or an extensive moor, or a great river-plain, containing room enough for individuals of every species in our island; yet the spot will be occupied by a few to the exclusion of many, and these few are enabled, throughout long periods, to maintain their ground successfully against every intruder, notwithstanding the facilities which species enjoy, by virtue of their power of diffusion, of invading adjacent territories.

The principal causes which enable a certain assemblage of plants thus to maintain their ground against all others depend, as is well known, on the relations between the physiological nature of each species, and the climate, exposure, soil, and other physical conditions of the locality. Some plants live only on rocks, others in meadows, a third class in marshes. Of the latter, some delight in a fresh-water morass,—others in salt marshes, where their roots may copiously absorb saline particles. Some prefer an alpine region in a warm latitude, where, during the heat of summer, they are constantly irrigated by the cool waters of melting snows. To others loose sand, so fatal to the

generality of species, affords the most proper station. The *Carex arenaria* and the *Elymus arenarius* acquire their full vigour on a sandy dune, obtaining an ascendancy over the very plants which in a stiff clay would immediately stifle them.

Where the soil of a district is of so peculiar a nature that it is extremely favourable to certain species, and agrees ill with every other, the former get exclusive possession of the ground, and as in the case of heaths, live in societies. In like manner the Bog moss (*Sphagnum palustre*) is fully developed in peaty swamps, and becomes, like the heath, in the language of botanists, a social plant. Such monopolies, however, are not common, for they are checked by various causes. Not only are many species endowed with equal powers to obtain and keep possession of similar stations, but each plant, for reasons not fully explained by the physiologist, has the property of rendering the soil where it has grown less fitted for the support of other individuals of its own species, or even other species of the same family. Yet the same spot, so far from being impoverished, is improved, for plants of another family. Oaks, for example, render the soil more fertile for the fir tribe, and firs prepare the soil for oaks. Every agriculturist feels the force of this law of the organic world, and regulates accordingly the rotation of his crops.

Equilibrium in the number of species, how preserved.
— “All the plants of a given country,” says De Candolle, in his usual spirited style, “are at war one with another. The first which establish themselves by chance in a particular spot tend, by the mere occupancy of space, to exclude other species—the greater choke the smaller; the longest livers replace those.

which last for a shorter period ; the more prolific gradually make themselves masters of the ground, which species multiplying more slowly would otherwise fill.”

In this continual strife it is not always the resources of the plant itself which enable it to maintain or extend its ground. Its success depends, in a great measure, on the number of its foes or allies, among the animals and plants inhabiting the same region. Thus, for example, a herb which loves the shade may multiply, if some tree with spreading boughs and dense foliage flourish in the neighbourhood. Another, which, if unassisted, would be overpowered by the rank growth of some hardy competitor, is secure because its leaves are unpalatable to cattle ; which, on the other hand, annually crop down its antagonist, and rarely suffer it to ripen its seed.

Oftentimes we see some herb which has flowered in the midst of a thorny shrub, when all the other individuals of the same species, in the open fields around, are eaten down, and cannot bring their seed to maturity. In this case, the shrub has lent his armour of spines and prickles to protect the defenceless herb against the mouths of the cattle ; and thus a few individuals which occupied, perhaps, the most unfavourable station in regard to exposure, soil, and other circumstances, may, nevertheless, by the aid of an ally, become the principal source whereby the winds are supplied with seeds which perpetuate the species throughout the surrounding tract. Thus, in the New Forest in Hampshire, the young oaks which are not consumed by the deer, or uprooted by the swine, are indebted to the holly for their escape.

In the above examples we see one plant shielding another from the attacks of animals ; but instances

are, perhaps, still more numerous, where some animal defends a plant against the enmity of some other subject of the vegetable kingdom.

Scarcely any beast, observes a Swedish naturalist, will touch the nettle, but fifty different kinds of insects are fed by it.* Some of these seize upon the root, others upon the stem; some eat the leaves; others devour the seeds and flowers: but for this multitude of enemies, the nettle (*Urtica dioica*), which is now found in all the four quarters of the globe, would annihilate a great number of plants. Linnæus tells us, in his "Tour in Scania," that goats were turned into an island which abounded with the *Agrostis arundinacea*, where they perished by famine; but horses which followed them grew fat on the same plant. The goat, also, he says, thrives on the meadow-sweet, and water-hemlock, plants which are injurious to cattle.†

Agency of insects. — Every plant, observes Wilcke, has its proper insect allotted to it to curb its luxuriancy, and to prevent it from multiplying to the exclusion of others. "Thus grass in meadows sometimes flourishes so as to exclude all other plants: here the Phalæna graminis (*Bombyx gram.*), with her numerous progeny, find a well-spread table; they multiply in immense numbers, and the farmer, for some years, laments the failure of his crop; but, the grass being consumed, the moths die with hunger, or remove to another place. Now the quantity of grass being greatly diminished, the other plants, which were before choked by it, spring up, and the ground becomes variegated

* Amœn. Acad. vol. vi. p. 17. § 12.

† Ibid. vol. vii. p. 409.

with a multitude of different species of flowers. Had not Nature given a commission to this minister for that purpose, the grass would destroy a great number of species of vegetables, of which the equilibrium is now kept up."*

In the above passage allusion is made to the ravages committed in 1740, and the two following years, in many provinces in Sweden, by a most destructive insect. The same moth is said never to touch the foxtail grass, so that it may be classed as a most active ally and benefactor of that species, and as peculiarly instrumental in preserving it in its present abundance.† A discovery of Rolander, cited in the treatise of Wilcke above mentioned, affords a good illustration of the checks and counter-checks which Nature has appointed to preserve the balance of power among species. "The *Phalæna strobilella* has the fir cone assigned to it to deposit its eggs upon; the young caterpillars coming out of the shell consume the cone and superfluous seed; but, lest the destruction should be too general, the *Ichneumon strobilellæ* lays its eggs in the caterpillar, inserting its long tail in the openings of the cone till it touches the included insect, for its body is too large to enter. Thus it fixes its minute egg upon the caterpillar, which being hatched destroys it."‡

Entomologists enumerate many parallel cases where insects, appropriated to certain plants, are kept down by other insects, and these again by parasites expressly

* Amœn. Acad. vol. vi. p. 17. § 11, 12.

† Kirby and Spence, vol. i. p. 178.

‡ Amœn. Acad. vol. vi. § 14.

appointed to prey on them.* Few, perhaps, are in the habit of duly appreciating the extent to which insects are active in preserving the balance of species among plants, and thus regulating indirectly the relative numbers of many of the higher orders of terrestrial animals.

The peculiarity of their agency consists in their power of suddenly multiplying their numbers to a degree which could only be accomplished in a considerable lapse of time in any of the larger animals, and then as instantaneously relapsing, without the intervention of any violent disturbing cause, into their former insignificance.

If, for the sake of employing, on different but rare occasions, a power of many hundred horses, we were under the necessity of feeding all these animals at great cost in the intervals when their services were not required, we should greatly admire the invention of a machine, such as the steam-engine, which was capable at any moment of exerting the same degree of strength without any consumption of food during periods of inaction. The same kind of admiration is strongly excited when we contemplate the powers of insect life, in the creation of which the Author of Nature has been so prodigal. A scanty number of minute individuals, to be detected only by careful research, are ready in a few days, weeks, or months, to give birth to myriads, which may repress any degree of monopoly in another species, or remove nuisances, such as dead carcasses, which might taint the air. But no sooner has the destroying commission been executed than the gigantic power becomes dormant—

* Kirby and Spence, vol. iv. p. 218.

each of the mighty host soon reaches the term of its transient existence, and the season arrives when the whole species passes naturally into the egg, and thence into the larva and pupa state. In this defenceless condition it may be destroyed either by the elements, or by the augmentation of some of its numerous foes which may prey upon it in these stages of its transformation; or it often happens that in the following year the season proves unfavourable to the hatching of the eggs or the development of the pupæ.

Thus the swarming myriads depart which may have covered the vegetation like the aphides, or darkened the air like locusts. In almost every season there are some species which in this manner put forth their strength, and then, like Milton's spirits, which thronged the spacious hall, "reduce to smallest forms their shapes immense"—

————— So thick the aëry crowd
Swarm'd and were straiten'd ; till, the signal given,
Behold a wonder ! they but now who seem'd
In bigness to surpass earth's giant sons,
Now less than smallest dwarfs.

A few examples will illustrate the mode in which this force operates. It is well known that, among the countless species of the insect creation, some feed on animal, others on vegetable matter; and, upon considering a catalogue of eight thousand British insects and arachnidæ, Mr. Kirby found that these two divisions were nearly a counterpoise to each other, the carnivorous being somewhat preponderant. There are also distinct species, some appointed to consume living, others dead or putrid animal and vegetable substances. One female, of *Musca carnaria*, will give

birth to twenty thousand young; and the larvæ of many flesh-flies devour so much food in twenty-four hours, and grow so quickly, as to increase their weight two hundred-fold! In five days after being hatched they arrive at their full growth and size, so that there was ground, says Kirby, for the assertion of Linnæus, that three flies of *M. vomitoria* could devour a dead horse as quickly as a lion *; and another Swedish naturalist remarks, that so great are the powers of propagation of a single species even of the smallest insects, that each can commit, when required, more ravages than the elephant.†

Next to locusts, the aphides, perhaps, exert the greatest power over the vegetable world, and, like them, are sometimes so numerous as to darken the air. The multiplication of these little creatures is without parallel, and almost every plant has its peculiar species. Reaumur has proved that in five generations one aphis may be the progenitor of 5,904,900,000 descendants; and it is supposed that in one year there may be twenty generations. ‡ Mr. Curtis observes that, as among caterpillars we find some that are constantly and unalterably attached to one or more particular species of plants, and others that feed indiscriminately on most sorts of herbage, so it is precisely with the aphides: some are particular, others more general, feeders; and as they resemble other insects in this respect, so they do also in being more abundant in some years than in others.§ In 1793 they were the chief, and in 1798 the sole, cause of the failure of the

* Kirby and Spence, vol. i. p. 250.

† Wilcke, Amœn. Acad. chap. ii.

‡ Kirby and Spence, vol. i. p. 174.

§ Trans. Linn. Soc. vol. vi.

hops. In 1794, a season almost unparalleled for drought, the hop was perfectly free from them; while peas and beans, especially the former, suffered very much from their depredations.

The ravages of the caterpillars of some of our smaller moths afford a good illustration of the temporary increase of a species. The oak-trees of a considerable wood have been stripped of their leaves as bare as in winter, by the caterpillars of a small green moth (*Tortrix viridana*), which has been observed the year following not to abound.* The silver Y moth (*Plusia gamma*), although one of our common species, is not dreaded by us for its devastations; but legions of their caterpillars have at times created alarm in France, as in 1735. Reaumur observes that the female moth lays about four hundred eggs; so that if twenty caterpillars were distributed in a garden, and all lived through the winter and became moths in the succeeding May, the eggs laid by these, if half of them were female and all fertile, would in the next generation produce 800,000 caterpillars.† A modern writer, therefore, justly observes that, did not Providence put causes in operation to keep them in due bounds, the caterpillars of this moth alone, leaving out of consideration the two thousand other British species, might soon destroy more than half of our vegetation.‡

In the latter part of the last century an ant most destructive to the sugar-cane (*Formica saccharivora*), appeared in such infinite hosts in the island of Grenada, as to put a stop to the cultivation of that vegetable. Their numbers were incredible. The plantations and

* Lib. Ent. Know., Insect Trans., p 203. See Haworth, Lep.

† Reaumur, ii. 337.

‡ Lib. Ent. Know., Insect Trans., p. 212.

roads were filled with them ; many domestic quadrupeds, together with rats, mice, and reptiles, and even birds, perished in consequence of this plague. It was not till 1780 that they were at length annihilated by torrents of rain, which accompanied a dreadful hurricane.*

Devastations caused by locusts. — We may conclude by mentioning some instances of the devastations of locusts in various countries. Among other parts of Africa, Cyrenaica has been at different periods infested by myriads of these creatures, which have consumed nearly every green thing. The effect of the havoc committed by them may be estimated by the famine they occasioned. St. Augustin mentions a plague of this kind in Africa which destroyed no less than 800,000 men in the kingdom of Masinissa alone, and many more upon the territories bordering upon the sea. It is also related, that in the year 591, an infinite army of locusts migrated from Africa into Italy ; and, after grievously ravaging the country, were cast into the sea, when there arose a pestilence from their stench which carried off nearly a million of men and beasts.

In the Venetian territory, also, in 1478, more than thirty thousand persons are said to have perished in a famine occasioned by this scourge ; and other instances are recorded of their devastations in France, Spain, Italy, Germany, &c. In different parts of Russia also, Hungary, and Poland, — in Arabia and India, and other countries, — their visitations have been periodically experienced. Although they have a preference for certain plants, yet, when these are consumed, they will

* Kirby and Spence, vol. i. p. 183. Castle, Phil. Trans., xxx. 346.

attack almost all the remainder. In the accounts of the invasions of locusts, the statements which appear most marvellous relate to the prodigious mass of matter which encumbers the sea wherever they are blown into it, and the pestilence arising from its putrefaction. Their dead bodies are said to have been, in some places, heaped one upon another, to the depth of four feet, in Russia, Poland, and Lithuania; and when, in southern Africa, they were driven into the sea by a north-west wind, they formed, says Barrow, along the shore, for fifty miles, a bank three or four feet high.* But when we consider that forests are stripped of their foliage, and the earth of its green garment, for thousands of square miles, it may well be supposed that the volume of animal matter produced may equal that of great herds of quadrupeds and flights of large birds suddenly precipitated into the sea.

The occurrence of such events at certain intervals, in hot countries, like the severe winters and damp summers returning after a series of years in the temperate zone, affect the proportional numbers of almost all classes of animals and plants, and are probably fatal to the existence of many which would otherwise thrive there; while, on the contrary, they must be favourable to certain species which, if deprived of such aid, might not maintain their ground.

Although it may usually be remarked that the extraordinary increase of some one species is immediately followed and checked by the multiplication of another, yet this does not always happen; partly because many species feed in common on the same kinds of food, and partly because many kinds of food are often consumed

* Travels in Africa, p. 257. Kirby and Spence, vol. i. p. 215.

indifferently by one and the same species. In the former case, where a variety of different animals have precisely the same taste, as, for example, when many insectivorous birds and reptiles devour alike some particular fly or beetle, the unusual numbers of these insects may cause only a slight and almost imperceptible augmentation of each of these species of bird and reptile. In the other instance, where one animal preys on others of almost every class, as, for example, where our English buzzards devour not only small quadrupeds, as rabbits and field-mice, but also birds, frogs, lizards, and insects, the profusion of any one of these last may cause all such general feeders to subsist more exclusively upon the species thus in excess, by which means the balance may be restored.

Agency of omnivorous animals. — The number of species which are nearly omnivorous is considerable; and although every animal has, perhaps, a predilection for some one description of food rather than another, yet some are not even confined to one of the great kingdoms of the organic world. Thus, when the racoon of the West Indies can procure neither fowls, fish, snails, nor insects, it will attack the sugar-canies, and devour various kinds of grain. The civets, when animal food is scarce, maintain themselves on fruits and roots.

Numerous birds, which feed indiscriminately on insects and plants, are perhaps more instrumental than any other of the terrestrial tribes in preserving a constant equilibrium between the relative numbers of different classes of animals and vegetables. If the insects become very numerous and devour the plants, these birds will immediately derive a larger portion of their subsistence from insects, just as the Arabians,

Syrians, and Hottentots feed on locusts, when the locusts devour their crops.

Reciprocal influence of aquatic and terrestrial species. — The intimate relation of the inhabitants of the water to those of the land, and the influence exerted by each on the relative number of species, must not be overlooked amongst the complicated causes which determine the existence of animals and plants in certain regions. A large portion of the amphibious quadrupeds and reptiles prey partly on aquatic plants and animals, and in part on terrestrial; and a deficiency of one kind of prey causes them to have immediate recourse to the other. The voracity of certain insects, as the dragon-fly, for example, is confined to the water during one stage of their transformations, and in their perfect state to the air. Innumerable water-birds, both of rivers and seas, derive in like manner their food indifferently from either element; so that the abundance or scarcity of prey in one induces them either to forsake or more constantly to haunt the other. Thus an intimate connexion between the state of the animate creation in a lake or river, and in the adjoining dry land, is maintained; or between a continent, with its lakes and rivers, and the ocean. It is well known that many birds migrate, during stormy seasons, from the sea-shore into the interior, in search of food; while others, on the contrary, urged by like wants, forsake their inland haunts, and live on substances rejected by the tide.

The migration of fish into rivers during the spawning season, supplies another link of the same kind. Suppose the salmon to be reduced in numbers by some marine foes, as by seals and grampuses, the consequence must often be, that in the course of a few years

the otters at the distance of several hundred miles inland, will be lessened in number from the scarcity of fish. On the other hand, if there be a dearth of food for the young fry of the salmon in rivers and estuaries, so that few return to the sea, the sand-eels and other marine species, which are usually kept down by the salmon, will swarm in greater profusion.

It is unnecessary to accumulate a greater number of illustrations in order to prove that the stations of different plants and animals depend on a great complication of circumstances,—on an immense variety of relations in the state of the animate and inanimate worlds. Every plant requires a certain climate, soil, and other conditions, and often the aid of many animals, in order to maintain its ground. Many animals feed on certain plants, being often restricted to a small number, and sometimes to one only; other members of the animal kingdom feed on plant-eating species, and thus become dependent on the conditions of the *stations* not only of their prey, but of the plants consumed by them.

Having duly reflected on the nature and extent of these mutual relations in the different parts of the organic and inorganic worlds, we may next proceed to examine the results which may be anticipated from the fluctuations now continually in progress in the state of the earth's surface, and in the geographical distribution of its living productions.

CHAPTER IX.

EXTINCTION OF SPECIES. — CHANGES IN THE STATIONS OF ANIMALS.

Extension of the range of one species alters the condition of many others — The first appearance of a new species causes the chief disturbance — Changes known to have resulted from the advance of human population — Whether man increases the productive powers of the earth — Indigenous quadrupeds and birds extirpated in Great Britain — Extinction of the dodo — Rapid propagation of domestic quadrupeds in America — Power of exterminating species no prerogative of man — Concluding remarks.

We have seen that the stations of animals and plants depend not merely on the influence of external agents in the inanimate world, and the relations of that influence to the structure and habits of each species, but also on the state of the contemporary living beings which inhabit the same part of the globe. In other words, the possibility of the existence of a certain species in a given place, or of its thriving more or less therein, is determined not merely by temperature, humidity, soil, elevation, and other circumstances of the like kind; but also by the existence or non-existence, the abundance or scarcity, of a particular assemblage of other plants and animals in the same region.

If it be shown that both these classes of circumstances, whether relating to the animate or inanimate creation, are perpetually changing, it will follow that species are subject to incessant vicissitudes; and if the

result of these mutations, in the course of ages, be so great as materially to affect the general condition of *stations*, it will follow that the successive destruction of species must now be part of the regular and constant order of nature.

Extension of the range of one species alters the condition of others.—It will be desirable, first, to consider the effects which every extension of the numbers or geographical range of one species must produce on the condition of others inhabiting the same regions. When the necessary consequences of such extensions have been fully explained, the reader will be prepared to appreciate the important influence which slight modifications in the physical geography of the globe may exert on the condition of organic beings.

In the first place, it is clear that when any region is stocked with as great a variety of animals and plants as the productive powers of that region will enable it to support, the addition of any new species, or the permanent numerical increase of one previously established, must always be attended either by the local extermination or the numerical decrease of some other species.

There may undoubtedly be considerable fluctuations from year to year, and the equilibrium may be again restored without any permanent alteration; for, in particular seasons, a greater supply of heat, humidity, or other causes, may augment the total quantity of vegetable produce, in which case all the animals subsisting on vegetable food, and others which prey on them, may multiply without any one species giving way: but whilst the aggregate quantity of vegetable produce remains unaltered, the progressive increase of one animal or plant implies the decline of another.

All agriculturists and gardeners are familiar with the fact that, when weeds intrude themselves into the space appropriated to cultivated species, the latter are starved in their growth or stifled. If we abandon for a short time a field or garden, a host of indigenous plants,

The darnel, hemlock, and rank fumitory, pour in and obtain the mastery, extirpating the exotics, or putting an end to the monopoly of some native plants.

If we inclose a park, and stock it with as many deer as the herbage will support, we cannot add sheep without lessening the number of the deer; nor can other herbivorous species be subsequently introduced, unless the individuals of each species in the park become fewer in proportion.

So, if there be an island where leopards are the only beasts of prey, and the lion, tiger, and hyæna afterwards enter, the leopards, if they stand their ground, will be reduced in number. If the locusts then arrive and swarm greatly, this may deprive a large number of plant-eating animals of their food, and thereby cause a famine, not only among them, but among the beasts of prey: certain species, perhaps, which had the weakest footing in the island may thus be annihilated.

We have seen how many distinct geographical provinces there are of aquatic and terrestrial species, and how great are the powers of migration conferred on different classes, whereby the inhabitants of one region may be enabled from time to time to invade another, and do actually so migrate and diffuse themselves over new countries. Now, although our knowledge of the history of the animate creation dates from so recent a

period, that we can scarcely trace the advance or decline of any animal or plant, except in those cases where the influence of man has intervened; yet we can easily conceive what must happen when some new colony of wild animals or plants enters a region for the first time, and succeeds in establishing itself.

Supposed effects of the first entrance of the polar bear into Iceland. — Let us consider how great are the devastations committed at certain periods by the Greenland bears, when they are drifted to the shores of Iceland in considerable numbers on the ice. These periodical invasions are formidable even to man; so that when the bears arrive, the inhabitants collect together, and go in pursuit of them with fire-arms — each native who slays one being rewarded by the king of Denmark. The Danes of old, when they landed in their marauding expeditions upon our coast, hardly excited more alarm; nor did our islanders muster more promptly for the defence of their lives and property against a common enemy, than the modern Icelanders against these formidable brutes. It often happens, says Henderson, that the natives are pursued by the bear when he has been long at sea, and when his natural ferocity has been heightened by the keenness of hunger; if unarmed, it is frequently by stratagem only that they make their escape.*

Let us cast our thoughts back to the period when the first polar bears reached Iceland, before it was colonized by the Norwegians in 874; we may imagine the breaking up of an immense barrier of ice, like that which, in 1816 and the following year, disappeared from the east coast of Greenland, which it had sur-

* *Journal of a Residence in Iceland*, p. 276.

rounded for four centuries. By the aid of such means of transportation a great number of these quadrupeds might effect a landing at the same time, and the havoc which they would make among the species previously settled in the island would be terrific. The deer, foxes, seals, and even birds, on which these animals sometimes prey, would be soon thinned down.

But this would be a part only, and probably an insignificant portion, of the aggregate amount of change brought about by the new invader. The plants on which the deer fed being less consumed in consequence of the lessened numbers of that herbivorous species, would soon supply more food to several insects, and probably to some terrestrial testacea, so that the latter would gain ground. The increase of these would furnish other insects and birds with food, so that the numbers of these last would be augmented. The diminution of the seals would afford a respite to some fish which they had persecuted ; and these fish, in their turn, would then multiply and press upon their peculiar prey. Many water-fowls, the eggs and young of which are devoured by foxes, would increase when the foxes were thinned down by the bears ; and the fish on which the water-fowls subsisted would then, in their turn, be less numerous. Thus the numerical proportions of a great number of the inhabitants, both of the land and sea, might be permanently altered by the settling of one new species in the region ; and the changes caused indirectly would ramify through all classes of the living creation, and be almost endless.

An actual illustration of what we have here only proposed hypothetically, is in some degree afforded by the selection of small islands by the eider duck for its residence during the season of incubation, its nests

being seldom if ever found on the shores of the main-land, or even of a large island. The Icelanders are so well aware of this, that they have expended a great deal of labour in forming artificial islands, by separating from the main-land certain promontories, joined to it by narrow isthmuses. This insular position is necessary to guard against the destruction of the eggs and young birds, by foxes, dogs, and other animals. One year, says Hooker, it happened that, in the small island of Vidoe, adjoining the coast of Iceland, a fox got over *upon the ice*, and caused great alarm, as an immense number of ducks were then sitting on their eggs or young ones. It was long before he was taken, which was at last, however, effected by bringing another fox to the island, and fastening it by a string near the haunt of the former, by which he was allured within shot of the hunter.*

The first appearance of a new species causes the chief disturbance. — It is usually the first appearance of an animal or plant, in a region to which it was previously a stranger, that gives rise to the chief alteration; since, after a time, an equilibrium is again established. But it must require ages before such a new adjustment of the relative forces of so many conflicting agents can be definitively settled. The causes in simultaneous action are so numerous, that they admit of an almost infinite number of combinations; and it is necessary that all these should have occurred once before the total amount of change, capable of flowing from any new disturbing force, can be estimated.

Thus, for example, suppose that once in two cen-

* Tour in Iceland, vol. i. p. 64., second edition.

turies a frost of unusual intensity, or a volcanic eruption of great violence accompanied by floods from the melting of glaciers, should occur in Iceland; or an epidemic disease, fatal to the larger number of individuals of some one species, and not affecting others,—these, and a variety of other contingencies, all of which may occur at once, or at periods separated by different intervals of time, ought to happen before it would be possible for us to declare what ultimate alteration the presence of any new comer, such as the bear before mentioned, might occasion in the animal population of the isle.

Every new condition in the state of the organic or inorganic creation, a new animal or plant, an additional snow-clad mountain, any permanent change, however slight in comparison to the whole, gives rise to a new order of things, and may make a material change in regard to some one or more species. Yet a swarm of locusts, or a frost of extreme intensity, or an epidemic disease, may pass away without any great apparent derangement; no species may be lost, and all may soon recover their former relative numbers, because the same scourges may have visited the region again and again, at preceding periods. Every plant that was incapable of resisting such a degree of cold, every animal which was exposed to be entirely cut off by an epidemic or by famine, caused by the consumption of vegetation by the locusts, may have perished already, so that the subsequent recurrence of similar catastrophes is attended only by a temporary change.

Changes caused by Man.

We are best acquainted with the mutations brought about by the progress of human population, and the

growth of plants and animals favoured by man. To these, therefore, we should in the first instance turn our attention. If we conclude, from the concurrent testimony of history and of the evidence yielded by geological data, that man is, comparatively speaking, of very modern origin, we must at once perceive how great a revolution in the state of the animate world the increase of the human race, considered merely as consumers of a certain quantity of organic matter, must necessarily cause.

Whether man increases the productive powers of the earth. — It may, perhaps, be said, that man has, in some degree, compensated for the appropriation to himself of so much food, by artificially improving the natural productiveness of soils, by irrigation, manure, and a judicious intermixture of mineral ingredients conveyed from different localities. But it admits of reasonable doubt whether, upon the whole, we fertilize or impoverish the lands which we occupy. This assertion may seem startling to many; because they are so much in the habit of regarding the sterility or productiveness of land in relation to the wants of man, and not as regards the organic world generally. It is difficult, at first, to conceive, if a morass is converted into arable land, and made to yield a crop of grain, even of moderate abundance, that we have not improved the capabilities of the habitable surface — that we have not empowered it to support a larger quantity of organic life. In such cases, however, a tract, before of no utility to man, may be reclaimed, and become of high agricultural importance, though it may, nevertheless, yield a scantier vegetation. If a lake be drained, and turned into a meadow, the space will provide sustenance to man, and many terrestrial animals service-

able to him, but not, perhaps, so much food as it previously yielded to the aquatic races.

If the pestiferous Pontine Marshes were drained, and covered with corn, like the plains of the Po, they might, perhaps, feed a smaller number of animals than they do now ; for these morasses are filled with herds of buffaloes and swine, and they swarm with birds, reptiles, and insects.

The felling of dense and lofty forests, which covered, even within the records of history, a considerable space on the globe, now tenanted by civilized man, must generally have lessened the amount of vegetable food throughout the space where these woods grew. We must also take into our account the area covered by towns, and a still larger surface occupied by roads.

If we force the soil to bear extraordinary crops one year, we are, perhaps, compelled to let it lie fallow the next. But nothing so much counterbalances the fertilizing effects of human art as the extensive cultivation of foreign herbs and shrubs, which, although they are often more nutritious to man, seldom thrive with the same rank luxuriance as the native plants of a district. Man is, in truth, continually striving to diminish the natural diversity of the *stations* of animals and plants in every country, and to reduce them all to a small number fitted for species of economical use. He may succeed perfectly in attaining his object, even though the vegetation be comparatively meagre, and the total amount of animal life be greatly lessened.

Spix and Martius have given a lively description of the incredible number of insects which lay waste the crops in Brazil, besides swarms of monkeys, flocks of parrots, and other birds, as well as the paca, agouti,

and wild swine. They describe the torment which the planter and the naturalist suffer from the mosquitoes, and the devastation of the ants and blattæ ; they speak of the dangers to which they were exposed from the jaguar, the poisonous serpents, crocodiles, scorpions, centipedes, and spiders. But with the increasing population and cultivation of the country, say these naturalists, these evils will gradually diminish ; when the inhabitants have cut down the woods, drained the marshes, made roads in all directions, and founded villages and towns, man will, by degrees, triumph over the rank vegetation and the noxious animals, and all the elements will second and amply recompense his activity.*

The number of human beings now peopling the earth is supposed to amount to eight hundred millions, so that we may easily understand how great a number of beasts of prey, birds, and animals of every class, this prodigious population must have displaced, independently of the still more important consequences which have followed from the derangement brought about by man in the relative numerical strength of particular species.

Indigenous quadrupeds and birds extirpated in Great Britain.— Let us make some inquiries into the extent of the influence which the progress of society has exerted during the last seven or eight centuries, in altering the distribution of indigenous British animals. Dr. Fleming has prosecuted this inquiry with his usual zeal and ability ; and in a memoir on the subject has enumerated the best authenticated examples of the decrease or extirpation of certain species during a

* Travels in Brazil, vol. i. p. 260.

period when our population has made the most rapid advances. I shall offer a brief outline of his results.*

The stag, as well as the fallow deer and the roe, were formerly so abundant in our island, that according to Lesley, from five hundred to a thousand were sometimes slain at a hunting-match; but the native races would already have been extinguished, had they not been carefully preserved in certain forests. The otter, the marten, and the polecat, were also in sufficient numbers to be pursued for the sake of their fur; but they have now been reduced within very narrow bounds. The wild cat and fox have also been sacrificed throughout the greater part of the country, for the security of the poultry-yard or the fold. Badgers have been expelled from nearly every district, which at former periods they inhabited.

Besides these, which have been driven out from some haunts, and every where reduced in number, there are some which have been wholly extirpated; such as the ancient breed of indigenous horses, and the wild boar; of the wild oxen, a few remains are still preserved in the parks of some of our nobility. The beaver, which was eagerly sought after for its fur, had become scarce at the close of the ninth century; and, by the twelfth century, was only to be met with, according to Giraldus de Barri, in one river in Wales, and another in Scotland. The wolf, once so much dreaded by our ancestors, is said to have maintained its ground in Ireland so late as the beginning of the eighteenth century (1710), though it had been extirpated in Scotland thirty years before, and in England at a much earlier period. The bear, which, in Wales,

* Ed. Phil. Journ. No. xxii. p. 287. Oct. 1824.

was regarded as a beast of the chase equal to the hare or the boar*, only perished, as a native of Scotland, in the year 1057.†

Many native birds of prey have also been the subjects of unremitting persecution. The eagles, larger hawks, and ravens, have disappeared from the more cultivated districts. The haunts of the mallard, the snipe, the redshank, and the bittern, have been drained equally with the summer dwellings of the lapwing and the curlew. But these species still linger in some portion of the British isles; whereas the larger capercailzies, or wood grouse, formerly natives of the pine-forests of Ireland and Scotland, have been destroyed within the last sixty years. The egret and the crane, which appear to have been formerly very common in Scotland, are now only occasional visitants. ‡

The bustard (*Otis tarda*), observes Graves, in his British Ornithology §, “was formerly seen in the downs and heaths of various parts of our island, in flocks of forty or fifty birds; whereas it is now a circumstance of rare occurrence to meet with a single individual.” Bewick also remarks, “that they were formerly more common in this island than at present; they are now found only in the open counties of the south and east — in the plains of Wiltshire, Dorsetshire, and some parts of Yorkshire.”|| In the few years that have elapsed since Bewick wrote, this bird has entirely disappeared from Wiltshire and Dorsetshire.

These changes, it may be observed, are derived from very imperfect memorials, and relate only to the

* Ray. *Syn. Quad.* p. 214.

† Fleming, *Ed. Phil. Journ.* No. xxii. p. 295.

‡ Fleming, *ibid.* p. 292. § Vol. iii. London, 1821.

|| *Land Birds*, vol. i. p. 316. ed. 1821.

larger and more conspicuous animals inhabiting a small spot on the globe ; but they cannot fail to exalt our conception of the enormous revolutions which, in the course of several thousand years, the whole human species must have effected.

Extinction of the Dodo. — The kangaroo and the emu are retreating rapidly before the progress of colonization in Australia ; and it scarcely admits of doubt, that the general cultivation of that country must lead to the extirpation of both. The most striking example of the loss, even within the last two centuries, of a remarkable species, is that of the dodo — a bird first seen by the Dutch, when they landed on the Isle of France, at that time uninhabited, immediately after the discovery of the passage to the East Indies by the Cape of Good Hope. It was of a large size, and singular form ; its wings short, like those of an ostrich, and wholly incapable of sustaining its heavy body, even for a short flight. In its general appearance it differed from the ostrich, cassowary, or any known bird.

Many naturalists gave figures of the dodo after the commencement of the seventeenth century ; and there is a painting of it in the British Museum, which is said to have been taken from a living individual. Beneath the painting is a leg, in a fine state of preservation, which ornithologists are agreed cannot belong to any other known bird. In the museum at Oxford, also, there is a foot and a head, in an imperfect state ; but M. Cuvier doubts the identity of this species with that of which the painting is preserved in London.

In spite of the most active search, during the last century, no information respecting the dodo was obtained, and some authors have gone so far as to pre-

tend that it never existed; but, amongst a great mass of satisfactory evidence in favour of the recent existence of this species, we may mention that an assemblage of fossil bones was recently discovered under a bed of lava, in the Isle of France, and sent to the Paris Museum, by M. Desjardins. They almost all belonged to a large living species of land-tortoise, called *Testudo Indica*; but amongst them were the head, sternum, and humerus of the dodo. M. Cuvier showed me these valuable remains in Paris, and assured me that they left no doubt in his mind that the huge bird was one of the gallinaceous tribe.*

Rapid propagation of domestic quadrupeds over the American continent. — Next to the direct agency of man, his indirect influence in multiplying the numbers of large herbivorous quadrupeds of domesticated races may be regarded as one of the most obvious causes of the extermination of species. On this, and on several other grounds, the introduction of the horse, ox, and other mammalia, into America, and their rapid propagation over that continent within the last three centuries, is a fact of great importance in natural history. The extraordinary herds of wild cattle and horses which overran the plains of South America sprung from a very few pairs first carried over by the Spaniards; and they prove that the wide geographical range of large species in great continents does not necessarily imply that they have existed there from remote periods.

Humboldt observes, in his Travels, on the authority of Azzara, that it is believed there exist, in the Pampas

* Sur quelques Ossemens, &c. — Ann. des Sci. tome xxi. p. 103. Sept. 1830.

of Buenos Ayres, twelve million cows and three million horses, without comprising, in this enumeration, the cattle that have no acknowledged proprietor. In the Llanos of Caraccas, the rich hateros, or proprietors of pastoral farms, are entirely ignorant of the number of cattle they possess. The young are branded with a mark peculiar to each herd, and some of the most wealthy owners mark as many as fourteen thousand a year.* In the northern plains, from the Orinoco to the lake of Maracaybo, M. Depons reckoned that 1,200,000 oxen, 180,000 horses, and 90,000 mules, wandered at large.† In some parts of the valley of the Mississippi, especially in the country of the Osage Indians, wild horses are immensely numerous.

The establishment of black cattle in America dates from Columbus's second voyage to St. Domingo. They there multiplied rapidly; and that island presently became a kind of nursery from which these animals were successively transported to various parts of the continental coast, and from thence into the interior. Notwithstanding these numerous exportations, in twenty-seven years after the discovery of the island, herds of four thousand head, as we learn from Oviedo, were not uncommon, and there were even some that amounted to eight thousand. In 1587, the number of hides exported from St. Domingo alone, according to Acosta's report, was 35,444; and in the same year there were exported 64,350 from the ports of New Spain. This was in the sixty-fifth year after the taking of Mexico, previous to which event the Spaniards, who came into that country, had not been able to engage in any thing else than war. ‡

* Pers. Nar. vol. iv.

† Quarterly Review, vol. xxi. p. 335.

‡ Ibid.

Every one is aware that these animals are now established throughout the American continent, from Canada to the Straits of Magellan.

The ass has thriven very generally in the New World; and we learn from Ulloa, that in Quito they ran wild, and multiplied in amazing numbers, so as to become a nuisance. They grazed together in herds, and when attacked defended themselves with their mouths. If a horse happened to stray into the places where they fed, they all fell upon him, and did not cease biting and kicking till they left him dead.*

The first hogs were carried to America by Columbus, and established in the island of St. Domingo the year following its discovery, in November, 1493. In succeeding years they were introduced into other places where the Spaniards settled; and, in the space of half a century, they were found established in the New World, from the latitude of 25° north, to the 40th degree of south latitude. Sheep, also, and goats have multiplied enormously in the New World, as have also the cat and the rat; which last, as before stated, has been imported unintentionally in ships. The dogs introduced by man which have at different periods become wild in America, hunted in packs, like the wolf and the jackal, destroying not only hogs, but the calves and foals of the wild cattle and horses.

Ulloa in his Voyage, and Buffon on the authority of old writers, relate a fact which illustrates very clearly the principle before explained, of the check which the increase of one animal necessarily offers to that of another. The Spaniards had introduced goats into the island of Juan Fernandez, where they became so

* Ulloa's Voyage. Wood's Zoog., vol. i. p. 9.

prolific as to furnish the pirates who infested those seas with provisions. In order to cut off this resource from the buccaneers, a number of dogs were turned loose into the island; and so numerous did they become in their turn, that they destroyed the goats in every accessible part, after which the number of the wild dogs again decreased. *

Increase of rein-deer imported into Iceland. — As an example of the rapidity with which a large tract may become peopled by the offspring of a single pair of quadrupeds, it may be mentioned that in the year 1773 thirteen rein-deer were exported from Norway, only three of which reached Iceland. These were turned loose into the mountains of Guldbringè Syssel, where they multiplied so greatly, in the course of forty years, that it was not uncommon to meet with herds, consisting of from forty to one hundred, in various districts.

The rein-deer, observes a modern writer, is in Lapland a loser by his connexion with man, but Iceland will be this creature's paradise. There is, in the interior, a tract which Sir G. Mackenzie computes at not less than forty thousand square miles, without a single human habitation, and almost entirely unknown to the natives themselves. There are no wolves; the Icelanders will keep out the bears; and the rein-deer, being almost unmolested by man, will have no enemy whatever, unless it has brought with it its own tormenting gadfly.†

Besides the quadrupeds before enumerated, our domestic fowls have also succeeded in the West Indies and America, where they have the common

* Buffon, vol. v. p. 100. Ulloa's Voyage, vol. ii. p. 220.

† Travels in Iceland in 1810, p. 342.

fowl, the goose, the duck, the peacock, the pigeon, and the guinea-fowl. As these were often taken suddenly from the temperate to very hot regions, they were not reared at first without much difficulty; but after a few generations, they became familiarized to the climate, which, in many cases, approached much nearer than that of Europe to the temperature of their original native countries.

The fact of so many millions of wild and tame individuals of our domestic species, almost all of them the largest quadrupeds and birds, having been propagated throughout the new continent within the short period that has elapsed since the discovery of America, while no appreciable improvement can have been made in the productive powers of that vast continent, affords abundant evidence of the extraordinary changes which accompany the diffusion and progressive advancement of the human race over the globe. That it should have remained for us to witness such mighty revolutions is a proof, even if there was no other evidence, that the entrance of man into the planet is, comparatively speaking, of extremely modern date, and that the effects of his agency are only beginning to be felt.

Population which the globe is capable of supporting.
— A modern writer has estimated, that there are in America upwards of four million square miles of useful soil, each capable of supporting 200 persons; and nearly six million, each mile capable of supporting 490 persons.* If this conjecture be true, it will follow, as that author observes, that if the natural resources of America were fully developed, it would afford sustenance to five times as great a number of inhabitants

* Maclaren, art. America, Encyc. Britannica.

as the entire mass of human beings existing at present upon the globe. The new continent, he thinks, though less than half the size of the old, contains an equal quantity of useful soil, and much more than an equal amount of productive power. Be this as it may, we may safely conclude that the amount of human population now existing constitutes but a small proportion of that which the globe is capable of supporting, or which it is destined to sustain at no distant period, by the rapid progress of society, especially in America, Australia, and certain parts of the old continent.

Power of exterminating species no prerogative of man.
— But if we reflect that many millions of square miles of the most fertile land, occupied originally by a boundless variety of animal and vegetable forms, have been already brought under the dominion of man, and compelled, in a great measure, to yield nourishment to him, and to a limited number of plants and animals which he has caused to increase, we must at once be convinced, that the annihilation of a multitude of species has already been effected, and will continue to go on hereafter, in certain regions, in a still more rapid ratio, as the colonies of highly civilized nations spread themselves over unoccupied lands.

Yet, if we wield the sword of extermination as we advance, we have no reason to repine at the havoc committed, nor to fancy, with the Scottish poet, that “we violate the social union of nature;” or complain, with the melancholy Jaques, that we

Are mere usurpers, tyrants, and what's worse,
To fright the animals and to kill them up
In their assign'd and native dwelling-place.

We have only to reflect, that in thus obtaining possession of the earth by conquest, and defending our

acquisitions by force, we exercise no exclusive prerogative. Every species which has spread itself from a small point over a wide area must, in like manner, have marked its progress by the diminution or the entire extirpation of some other, and must maintain its ground by a successful struggle against the encroachments of other plants and animals. That minute parasitic plant, called "the rust" in wheat, has, like the Hessian fly, the locust, and the aphis, caused famines ere now amongst the "lords of the creation." The most insignificant and diminutive species, whether in the animal or vegetable kingdom, have each slaughtered their thousands, as they disseminated themselves over the globe, as well as the lion, when first it spread itself over the tropical regions of Africa.

Concluding remarks. — Although we have as yet considered one class only of the causes (the organic) by which species may become exterminated, yet it cannot but appear evident that the continued action of these alone, throughout myriads of future ages, must work an entire change in the state of the organic creation, not merely on the continents and islands, where the power of man is chiefly exerted, but in the great ocean, where his control is almost unknown. The mind is prepared by the contemplation of such future revolutions to look for the signs of others, of an analogous nature, in the monuments of the past. Instead of being astonished at the proofs there manifested of endless mutations in the animate world, they will appear to one who has thought profoundly on the fluctuations now in progress, to afford evidence in favour of the uniformity of the system, unless, indeed, we are precluded from speaking of *uniformity* when we characterize a principle of endless variation.

CHAPTER X.

EXTINCTION OF SPECIES.—INFLUENCE OF INORGANIC CAUSES.

Powers of diffusion indispensable, that each species may maintain its ground — How changes in physical geography affect the distribution of species — Rate of the change of species due to this cause cannot be uniform — Every change in the physical geography of large regions tends to the extinction of species — Effects of a general alteration of climate on the migration of species — Gradual refrigeration would cause species in the northern and southern hemispheres to become distinct — elevation of temperature the reverse — Effects on the condition of species which must result from inorganic changes inconsistent with the theory of transmutation.

Powers of diffusion indispensable, that each species may maintain its ground. — HAVING shown in the last chapter how considerably the numerical increase or the extension of the geographical range of any one species must derange the numbers and distribution of others, let us now direct our attention to the influence which the inorganic causes described in the second book are continually exerting on the habitations of species.

So great is the instability of the earth's surface, that if nature were not continually engaged in the task of sowing seeds and colonizing animals, the depopulation of a certain portion of the habitable sea and land would

in a few years be considerable. Whenever a river transports sediment into a lake or sea, so as materially to diminish its depth, the aquatic animals and plants which delight in deep water are expelled: the tract, however, is not allowed to remain useless; but is soon peopled by species which require more light and heat, and thrive where the water is shallow. Every addition made to the land by the encroachment of the delta of a river, banishes many subaqueous species from their native abodes; but the new-formed plain is not permitted to lie unoccupied, being instantly covered with terrestrial vegetation. The ocean devours continuous lines of sea-coast, and precipitates forests or rich pasture land into the waves: but this space is not lost to the animate creation; for shells and sea-weed soon adhere to the new-made cliffs, and numerous fish people the channel which the current has scooped out for itself. No sooner has a volcanic island been thrown up than some lichens begin to grow upon it, and it is sometimes clothed with verdure while smoke and ashes are still occasionally thrown from the crater. The cocoa, pandanus, and mangrove take root upon the coral reef before it has fairly risen above the waves. The burning stream of lava that descends from Etna rolls through the stately forest, and converts to ashes every tree and herb which stands in its way; but the black strip of land thus desolated is covered again, in the course of time, with oaks, pines, and chestnuts, as luxuriant as those which the fiery torrent swept away.

Every flood and landslip, every wave which a hurricane or earthquake throws upon the shore, every shower of volcanic dust and ashes which buries a country far and wide to the depth of many feet, every

advance of the sand-flood, every conversion of salt-water into fresh, when rivers alter their main channel of discharge, every permanent variation in the rise or fall of tides in an estuary — these and countless other causes displace, in the course of a few centuries, certain plants and animals from stations which they previously occupied. If, therefore, the Author of nature had not been prodigal of those numerous contrivances, before alluded to, for spreading all classes of organic beings over the earth — if he had not ordained that the fluctuations of the animate and inanimate creation should be in perfect harmony with each other, it is evident that considerable spaces, now the most habitable on the globe, would soon be as devoid of life as are the Alpine snows, or the dark abysses of the ocean, or the moving sands of the Sahara.

The powers, then, of migration and diffusion conferred on animals and plants are indispensable to enable them to maintain their ground, and would be necessary, even though it were never intended that a species should gradually extend its geographical range. But a facility of shifting their quarters being once given, it cannot fail to happen that the inhabitants of one province should occasionally penetrate into some other ; since the strongest of those barriers which I before described as separating distinct regions are all liable to be thrown down, one after the other, during the vicissitudes of the earth's surface.

How changes in physical geography affect the distribution of species.— The numbers and distribution of particular species are affected in two ways, by changes in the physical geography of the earth : — First, these changes promote or retard the migrations of species ; secondly, they alter the physical conditions of the

localities which species inhabit. If the ocean should gradually wear its way through an isthmus, like that of Suez, it would open a passage for the intermixture of the aquatic tribes of two seas previously disjoined, and would, at the same time, close a free communication which the terrestrial plants and animals of two continents had before enjoyed. These would be, perhaps, the most important consequences, in regard to the distribution of species, which would result from the breach made by the sea in such a spot; but there would be others of a distinct nature, such as the conversion of a certain tract of land, which formed the isthmus, into sea. This space, previously occupied by terrestrial plants and animals, would be immediately delivered over to the aquatic; a local revolution which might have happened in innumerable other parts of the globe, without being attended by any alteration in the blending together of species of two distinct provinces.

Rate of change of species cannot be uniform. — This observation leads me to point out one of the most interesting conclusions to which we are led by the contemplation of the vicissitudes of the inanimate world in relation to those of the animate. It is clear that, if the agency of inorganic causes be uniform, as I have supposed, they must operate very irregularly on the state of organic beings, so that the rate according to which these will change in particular regions will not be equal in equal periods of time.

I am not about to advocate the doctrine of general catastrophes recurring at certain intervals, as in the ancient Oriental cosmogonies, nor do I doubt that, if very considerable periods of equal duration could be compared one with another, the rate of change in the

living, as well as in the inorganic world, might be nearly uniform; but if we regard each of the causes separately, which we know to be at present the most instrumental in remodelling the state of the surface, we shall find that we must expect each to be in action for thousands of years, without producing any extensive alterations in the habitable surface, and then to give rise, during a very brief period, to important revolutions.

Illustration derived from subsidences.—I shall illustrate this principle by a few of the most remarkable examples which present themselves. In the course of the last century, as we have seen, a considerable number of instances are recorded of the solid surface, whether covered by water or not, having been permanently sunk or upraised by subterranean movements. Most of these convulsions are only accompanied by temporary fluctuations in the state of limited districts, and a continued repetition of these events for thousands of years might not produce any decided change in the state of many of those great zoological or botanical provinces of which I have sketched the boundaries.

When, for example, large parts of the ocean and even of inland seas are a thousand fathoms or upwards in depth, it is a matter of no moment to the animate creation that vast tracts should be heaved up many fathoms at certain intervals, or should subside to the same amount. Neither can any material revolution be produced in South America either in the terrestrial or the marine plants or animals by a series of shocks on the coast of Chili, each of which, like that of Penco, in 1751, should uplift the coast about twenty-five feet. Nor if the ground sinks fifty feet at a time, as in the

harbour of Port Royal, in Jamaica, in 1692, will such alterations of level work any general fluctuations in the state of organic beings inhabiting the West India islands, or the Caribbean Sea.

It is only when these subterranean powers, by shifting gradually the points where their principal force is developed, happen to strike upon some particular region where a slight change of level immediately affects the distribution of land and water, or the state of the climate, or the barriers between distinct groups of species over extensive areas, that the rate of fluctuation becomes accelerated, and may, in the course of a few years or centuries, work mightier changes than had been experienced in myriads of antecedent years.

Thus, for example, a repetition of subsidences causing the narrow isthmus of Panama to sink down a few hundred feet, would, in a few centuries, bring about a great revolution in the state of the animate creation in the western hemisphere. Thousands of aquatic species would pass, for the first time, from the Caribbean Sea into the Pacific ; and thousands of others, before peculiar to the Pacific Ocean, would make their way into the Caribbean Sea, the Gulf of Mexico, and the Atlantic. A considerable modification would probably be occasioned by the same event in the direction or volume of the Gulf stream, and thereby the temperature of the sea and the contiguous lands might be altered as far as the influence of that current extends. A change of climate might thus be produced in the ocean from Florida to Spitzbergen, and in many countries of North America, Europe, and Greenland. Not merely the heat, but the quantity of rain which falls, would be altered in certain districts, so that many species would be excluded from tracts where they before flourished : others would be

reduced in number ; and some would thrive more and multiply. The seeds also and the fruits of plants would no longer be drifted in precisely the same directions, nor the eggs of aquatic animals ; neither would species be any longer impeded in their migrations towards particular stations before shut out from them by their inability to cross the mighty current.

Let us take another example from a part of the globe which is at present liable to suffer by earthquakes, namely, the low sandy tract which intervenes between the Sea of Azof and the Caspian. If there should occur a sinking down to a trifling amount, and such ravines should be formed as might be produced by a few earthquakes, not more considerable than have fallen within our limited observation during the last 150 years, the waters of the Sea of Azof would pour rapidly into the Caspian, which, according to the measurements lately made by the Academy of St. Petersberg, is 108 feet below the level of the Black Sea.* The Sea of Azof would immediately borrow from the Black Sea, that sea again from the Mediterranean, and the Mediterranean from the Atlantic, so that an inexhaustible current would pour down into the low tracts of Asia bordering the Caspian, by which all the sandy salt steppes adjacent to that sea would be inundated. An area of several thousand square leagues, now below the level of the Mediterranean, would be converted from land into sea.

The diluvial waters would reach the salt lake of Aral, nor stop until their eastern shores were bounded by the high land which in the steppe of the Kirghis connects the Altay with the Himalaya Mountains. Saratof,

* See a note on this subject, Book I, chap. x.

Orenburg, and the low regions of the Oxus and Jaxartes, would be submerged. A few years, perhaps a few months, might suffice for the accomplishment of this great revolution in the geography of the interior of Asia; and it is impossible for those who believe in the permanence of the energy with which existing causes now act, not to anticipate analogous events again and again in the course of future ages.

Illustration derived from the elevation of land. — Let us next imagine a few cases of the elevation of land of small extent at certain critical points, as, for example, in the shallowest part of the Straits of Gibraltar, where the deepest soundings from the African to the European side give only 220 fathoms. In proportion as this submarine barrier of rock was upheaved, the whole channel would be contracted in width and depth, and the volume of water which the current constantly flowing from the Atlantic pours into the Mediterranean would be lessened. But the loss of the inland sea by evaporation would remain the same; so that being no longer able to draw on the ocean for a supply sufficient to restore its equilibrium, it must sink, and leave dry a certain portion of land around its borders. The current which now flows constantly out of the Black Sea into the Mediterranean would then rush in more rapidly, and the level of the Mediterranean would be thereby prevented from falling so low; but the level of the Black Sea would, for the same reason, sink; so that when, by a continued series of elevatory movements, the Straits of Gibraltar had become completely closed up, we might expect large and level sandy steppes to surround both the Black Sea and Mediterranean, like those occurring at present on the skirts of the Caspian, and the Lake of Aral. The geographical

range of hundreds of aquatic species would be thereby circumscribed, and that of hundreds of terrestrial plants and animals extended.

A line of submarine volcanos crossing the channel of some strait, and gradually choking it up with ashes and lava, might produce a new barrier as effectually as a series of earthquakes; especially if thermal springs, charged with carbonate of lime, silica, and other mineral ingredients, should promote the rapid multiplication of corals and shells, and cement them together with solid matter precipitated during the intervals between eruptions. Suppose in this manner a stoppage to be caused of the Bahama channel between the bank of that name and the coast of Florida. This insignificant revolution, confined to a mere spot in the bottom of the ocean, would, by diverting the main current of the Gulf stream, give rise to extensive changes in the climate and distribution of animals and plants inhabiting the northern hemisphere.

Illustration from the formation of new islands.—A repetition of elevatory movements of earthquakes might continue over an area as extensive as Europe, for thousands of ages, at the bottom of the ocean, in certain regions, and produce no visible effects; whereas, if they should operate in some shallow parts of the Pacific, amid the coral archipelagos, they would soon give birth to a new continent. Hundreds of volcanic islands may be thrown up, and become covered with vegetation, without causing more than local fluctuations in the animate world; but if a chain like the Aleutian archipelago, or the Kurile Isles, run for a distance of many hundred miles, so as to form an almost uninterrupted communication between two continents, or two distant islands, the migrations of plants, birds,

insects, and even of some quadrupeds, may cause, in a short time, an extraordinary series of revolutions tending to augment the range of some animals and plants, and to limit that of others. A new archipelago might be formed in the Mediterranean, the Bay of Biscay, and a thousand other places, and might produce less important events than one rock which should rise up between Australia and Java, so placed that winds and currents might cause an interchange of the plants, insects, and birds.

From the wearing through of an isthmus.—If we turn from the igneous to the aqueous agents, we find the same tendency to an irregular rate of change, naturally connected with the strictest uniformity in the energy of those causes. When the sea, for example, gradually encroaches upon both sides of a narrow isthmus, as that of Sleswick, separating the North Sea from the Baltic, where, as before stated, the cliffs on both the opposite coasts are wasting away*, no material alteration results for thousands of years, save only that there is a progressive conversion of a small strip of land into water. A few feet only, or a few yards, are annually removed; but when, at last, the partition shall be broken down, and the tides of the ocean shall enter by a direct passage into the inland sea, instead of going by a circuitous route through the Cattegat, a body of salt water will sweep up as far as the Gulfs of Bothnia and Finland, the waters of which are now brackish, or almost fresh; and this revolution will be attended by the local annihilation of many species.

Similar consequences must have resulted, on a small scale, when the sea opened its way through the isthmus

* See Vol. II. p. 90.

of Staveren in the thirteenth century, forming a union between an inland lake and the ocean, and opening, in the course of one century, a shallow strait, more than half as wide as the narrowest part of that which divides England from France.

Changes in physical geography which must occasion extinction of species. — It will almost seem superfluous, after I have thus traced the important modifications in the condition of living beings which flow from changes of trifling extent, to argue that entire revolutions might be brought about, if the climate and physical geography of the whole globe were greatly altered. It has been stated, that species are in general local, some being confined to extremely small spots, and depending for their existence on a combination of causes, which, if they are to be met with elsewhere, occur only in some very remote region. Hence it must happen that, when the nature of these localities is changed, the species will perish; for it will rarely happen that the cause which alters the character of the district will afford new facilities to the species to establish itself elsewhere.

African desert. — If we attribute the origin of a great part of the desert of Africa to the gradual progress of moving sands, driven eastward by the westerly winds, we may safely infer that a variety of species must have been annihilated by this cause alone. The sand-flood has been inundating, from time immemorial, some of the rich lands on the west of the Nile; and we have only to multiply this effect a sufficient number of times, in order to understand how, in the lapse of ages, a whole group of terrestrial animals and plants may become extinct.

The African desert, without including Bornou and Darfour, extends, according to the calculation of Humboldt, over 194,000 square leagues; an area nearly three times as great as that of France. In a small portion of so vast a space, we may infer from analogy that there were many peculiar species of plants and animals which must have been banished by the sand, and their habitations invaded by the camel, and by birds and insects formed for the arid sands.

There is evidently nothing in the nature of the catastrophe to favour the escape of the former inhabitants to some adjoining province; nothing to weaken, in the bordering lands, that powerful barrier against emigration — pre-occupancy. Nor, even if the exclusion of a certain group of species from a given tract were compensated by an extension of their range over a new country, would that circumstance tend to the conservation of species in general; for the extirpation would merely then be transferred to the region so invaded. If it be imagined, for example, that the aboriginal quadrupeds, birds, and other animals of Africa, emigrated in consequence of the advance of drift-sand, and colonized Arabia, the indigenous Arabian species must have given way before them, and have been reduced in number or destroyed.

Let us next suppose that, in some central and more elevated parts of the great African desert, the upheaving power of subterranean movements should be exerted throughout an immense series of ages, accompanied, at certain intervals, by volcanic eruptions, such as gave rise at once, in 1755, to a mountain 1600 feet high, on the Mexican plateau. When the continued repetition of these events had caused a mountain-

chain, it is obvious that a complete transformation in the state of the climate would be brought about throughout a vast area.

We may imagine the summits of the new chain to rise so high as to be covered, like Mount Atlas, for several thousand feet, with snow, during a great part of the year. The melting of these snows, during the greatest heat, would cause the rivers to swell in the season when the greatest drought now prevails ; the waters, moreover, derived from this source, would always be of lower temperature than the surrounding atmosphere, and would thus contribute to cool the climate. During the numerous earthquakes and volcanic eruptions supposed to accompany the gradual formation of the chain, there would be many floods caused by the bursting of temporary lakes, and by the melting of snows by lava. These inundations might deposit alluvial matter far and wide over the original sands, as the country assumed varied shapes, and was modified again and again by the moving power from below, and the aqueous erosion of the surface above. At length the Sahara might be fertilized, irrigated by rivers and streamlets intersecting it in every direction, and covered by jungle and morasses ; so that the animals and plants which now people Northern Africa would disappear, and the region would gradually become fitted for the reception of a population of species perfectly dissimilar in their forms, habits, and organization.

There are always some peculiar and characteristic features in the physical geography of each large division of the globe ; and on these peculiarities the state of animal and vegetable life is dependent. If.

therefore, we admit incessant fluctuations in the physical geography, we must, at the same time, concede the successive extinction of terrestrial and aquatic species to be part of the economy of our system. When some great class of *stations* is in excess in certain latitudes, as, for example, in wide savannahs, arid sands, lofty mountains, or inland seas, we find a corresponding development of species adapted for such circumstances. In North America, where there is a chain of vast inland lakes of fresh water, we find an extraordinary abundance and variety of aquatic birds, fresh-water fish, testacea, and small amphibious reptiles, fitted for such a climate. The greater part of these would perish if the lakes were destroyed,—an event that might be brought about by some of the least of those important revolutions contemplated in geology. It might happen that no fresh-water lakes of corresponding magnitude might then exist on the globe; or that, if they occurred elsewhere, they might be situated in New Holland, Southern Africa, Eastern Asia, or some region so distant as to be quite inaccessible to the North American species; or they might be situated within the tropics, in a climate uninhabitable by creatures fitted for a temperate zone; or, finally, we may presume that they would be pre-occupied by *indigenous* tribes.

A vivid description has been given by Mr. Darwin and Sir W. Parish of the great droughts which have sometimes visited the Pampas of South America, for three or four years in succession, during which an incredible number of wild animals, cattle, horses, and birds, have perished from want of food and water. Several hundred thousand animals were drowned in the Parana

alone, having rushed into the river to drink, and being too much exhausted by hunger to escape.* Such droughts are often attended in South America and other hot climates by wide-spreading conflagrations, caused by lightning, which fires the dried grass and brushwood. Thus quadrupeds, birds, insects, and other creatures, are destroyed by myriads. How many species, both of the animal and vegetable world, which once flourished in the country between the valley of the Parana and the straits of Magellan, may not have been annihilated, since the first drought or first conflagration began !

To pursue this train of reasoning farther is unnecessary ; the geologist has only to reflect on what has been said of the habitations and stations of organic beings in general, and to consider them in relation to those effects which were contemplated in the second book, as resulting from the igneous and aqueous causes now in action, and he will immediately perceive that, amidst the vicissitudes of the earth's surface, species cannot be immortal, but must perish, one after the other, like the individuals which compose them. There is no possibility of escaping from this conclusion, without resorting to some hypothesis as violent as that of Lamarck, who imagined, as we have before seen, that species are each of them endowed with indefinite powers of modifying their organization, in conformity to the endless changes of circumstances to which they are exposed.

* Darwin's Journal, p. 156. Sir W. Parish, Buenos Ayres, &c. pp. 371. and 151.

Effects of a general Alteration in Climate on the Distribution of Species.

Some of the effects which must attend every general alteration of *climate* are sufficiently peculiar to claim a separate consideration before concluding the present chapter.

I have before stated that, during seasons of extraordinary severity, many northern birds, and in some countries many quadrupeds, migrate southwards. If these cold seasons were to become frequent, in consequence of a gradual and general refrigeration of the atmosphere, such migrations would be more and more regular, until, at length, many animals, now confined to the arctic regions, would become the tenants of the temperate zone; while the inhabitants of the temperate zone would approach nearer to the equator. At the same time, many species previously established on high mountains would begin to descend, in every latitude, towards the middle regions; and those which were confined to the flanks of mountains would make their way into the plains. Analogous changes would also take place in the vegetable kingdom.

If, on the contrary, the heat of the atmosphere be on the increase, the plants and animals of low grounds would ascend to higher levels, the equatorial species would migrate into the temperate zone, and those of the temperate into the arctic circle.

But although some species might thus be preserved, every great change of climate must be fatal to many which can find no place of retreat when their original habitations become unfit for them. For if the general temperature be on the rise, then there is no cooler region whither the polar species can take refuge; if it

be on the decline, then the animals and plants previously established between the tropics have no resource. Suppose the general heat of the atmosphere to increase, so that even the arctic region became too warm for the musk-ox and reindeer, it is clear that they must perish ; so if the torrid zone should lose so much of its heat by the progressive refrigeration of the earth's surface as to be an unfit habitation for apes, boas, bamboos, and palms, these tribes of animals and plants, or, at least, most of the species now belonging to them, would become extinct, for there would be no warmer latitudes for their reception.

It will follow, therefore, that as often as the climates of the globe are passing from the extreme of heat to that of cold — from the summer to the winter of the great year before alluded to * — the migratory movement will be directed constantly from the poles towards the equator ; and for this reason the species inhabiting parallel latitudes, in the northern and southern hemispheres, must become widely different. For I assume on grounds before explained, that the original stock of each species is introduced into one spot of the earth only, and, consequently, no species can be at once indigenous in the arctic and antarctic circles.†

But when, on the contrary, a series of changes in the physical geography of the globe, or any other supposed cause, occasions an elevation of the general temperature,—when there is a passage from the winter to one of the vernal or summer seasons of the great cycle of climate, — then the order of the migratory movement is inverted. The different species of ani-

* Book I. chap. vii.

† See chap. viii.

mals and plants direct their course from the equator towards the poles; and the northern and southern hemispheres may become peopled to a great degree by identical species. Such is not the actual state of the inhabited earth, as I have already shown in my sketch of the geographical distribution of its living productions; and this fact adds an additional proof to the geological evidence, derived from independent sources, that the general temperature has been cooling down during the epochs which immediately preceded our own.

I do not mean to speculate on the entire transposition of a group of animals and plants from tropical to polar latitudes, or the reverse, as a probable, or even possible, event; for although we may believe the mean annual temperature of one zone to be transferable to another, we know that the same climate cannot be so transferred. Whatever be the general temperature of the earth's surface, comparative equability of heat will characterize the tropical regions; while great periodical variations will belong to the temperate, and still more to the polar, latitudes. These, and many other peculiarities connected with heat and light, depend on fixed astronomical causes, such as the motion of the earth and its position in relation to the sun, and not on those fluctuations of its surface, which may influence the general temperature.

Among many obstacles to such extensive transference of habitations we must not forget the immense lapse of time required, according to the hypothesis before suggested, to bring about a considerable change in climate. During a period so vast, the other causes of extirpation, before enumerated, would exert so powerful an influence as to prevent all, save a very

few hardy species, from passing from equatorial to polar regions, or from the tropics to the pole.*

But the power of accommodation to new circumstances is great in certain species, and might enable many to pass from one zone to another, if the mean annual heat of the atmosphere and the ocean were greatly altered. To the marine tribes, especially, such a passage would be possible ; for they are less impeded in their migrations by barriers of land, than are the terrestrial by the ocean. Add to this, that the temperature of the ocean is much more uniform than that of the atmosphere investing the land ; so that we may easily suppose that most of the testacea, fish, and other classes, might pass from the equatorial into the temperate regions, if the mean temperature of those regions were transposed, although a second expatriation of these species of tropical origin into the arctic and antarctic circles would probably be impossible.

On the principles above explained, if we found that at some former period, as when, for example, our carboniferous strata were deposited, the same tree-ferns and other plants inhabited the regions now occupied by Europe and Van Diemen's Land, we should suspect that the species in question had, at some antecedent period, inhabited lands within the tropics, and that an increase of the mean annual heat had caused them to emigrate into both the temperate zones. There are no geological data, however, as yet obtained, to warrant the opinion that such identity of species existed in the two hemispheres in the era in question.

Let us now consider more particularly the effect of vicissitudes of climate in causing one species to give way before the increasing numbers of some other.

* See Book I. chap. vi. vii. and viii.

When temperature forms the barrier which arrests the progress of an animal or plant in a particular direction, the individuals are fewer and less vigorous as they approach the extreme confines of the geographical range of the species. But these stragglers are ready to multiply rapidly on the slightest increase or diminution of heat that may be favourable to them, just as particular insects increase during a hot summer, and certain plants and animals gain ground after a series of congenial seasons.

In almost every district, especially if it be mountainous, there are a variety of species the limits of whose habitations are conterminous, some being unable to proceed farther without encountering too much heat, others too much cold. Individuals, which are thus on the borders of the regions proper to their respective species, are like the outposts of hostile armies, ready to profit by every slight change of circumstances in their favour, and to advance upon the ground occupied by their neighbours and opponents.

The proximity of distinct climates, produced by the inequalities of the earth's surface, brings species possessing very different constitutions into such immediate contact, that their naturalizations are very speedy whenever opportunities of advancing present themselves. Many insects and plants, for example, are common to low plains within the arctic circle, and to lofty mountains in Scotland and other parts of Europe. If the climate, therefore, of the polar regions were transferred to our own latitudes, the species in question would immediately descend from these elevated stations to overrun the low grounds. Invasions of this kind, attended by the expulsion of the pre-occupants, are almost instantaneous, because the change of tem-

perature not only places the one species in a more favourable position, but renders the others sickly and almost incapable of defence.

These changes inconsistent with the theory of transmutation. — Lamarck, when speculating on the transmutation of species, supposed every modification in organization and instinct to be brought about slowly and insensibly in an indefinite lapse of ages.* But he does not appear to have sufficiently considered how much every alteration in the physical condition of the habitable surface changes the relations of a great number of co-existing species, and that some of these would be ready instantly to avail themselves of the slightest change in their favour, and to multiply to the injury of others. Even if we thought it possible that the palm or the elephant, which now flourish in equatorial regions, could ever learn to bear the variable seasons of our temperate zone, or the rigours of an arctic winter, we might, with no less confidence, affirm, that they must perish before they had time to become habituated to such new circumstances. That they would be displaced by other species as often as the climate varied, may be inferred from the data before explained respecting the local extermination of species produced by the multiplication of others.

Suppose the climate of the highest part of the woody zone of Etna to be transferred to the sea-shore at the base of the mountain, no botanist would anticipate that the olive, lemon-tree, and prickly pear (*Cactus Opuntia*), would be able to contend with the oak and chestnut, which would begin forthwith to descend to a lower level; or that these last would be

* See p. 3.

able to stand their ground against the pine, which would also, in the space of a few years, begin to occupy a lower position. We might form some kind of estimate of the time which might be required for the migrations of these plants; whereas we have no data for concluding that any number of thousands of years would be sufficient for one step in the pretended metamorphosis of one species into another, possessing distinct attributes and qualities.

This argument is applicable not merely to *climate*, but to any other cause of mutation. However slowly a lake may be converted into a marsh, or a marsh into a meadow, it is evident that before the lacustrine plants can acquire the power of living in marshes, or the marsh-plants of living in a less humid soil, other species, already existing in the region, and fitted for these several stations, will intrude and keep possession of the ground. So, if a tract of salt water becomes fresh by passing through every intermediate degree of brackishness, still the marine mollusks will never be permitted to be gradually metamorphosed into fluviatile species; because long before any such transformation can take place by slow and insensible degrees, other tribes, already formed to delight in brackish or fresh water, will avail themselves of the change in the fluid, and will, each in their turn, monopolize the space.

It is idle, therefore, to dispute about the abstract possibility of the conversion of one species into another, when there are known causes so much more active in their nature, which must always intervene and prevent the actual accomplishment of such conversions. A faint image of the certain doom of a species less fitted to struggle with some new condition in a region which it previously inhabited, and where it has to contend

with a more vigorous species, is presented by the extirpation of savage tribes of men by the advancing colony of some civilized nation. In this case the contest is merely between two different *races* — two varieties, moreover, of a species which exceeds all others in its aptitude to accommodate its habits to the most extraordinary variations of circumstances. Yet few future events are more certain than the speedy extermination of the Indians of North America and the savages of New Holland in the course of a few centuries, when these tribes will be remembered only in poetry, history, or tradition.

CHAPTER XI.

EXTINCTION AND CREATION OF SPECIES.

Theory of the successive extinction of species consistent with a limited geographical distribution — Opinions of botanists respecting the centres from which plants have been diffused — Whether there are grounds for inferring that the loss, from time to time, of certain animals and plants, is compensated by the introduction of new species? — Whether any evidence of such new creations could be expected within the historical era? — The question whether the existing species have been created in succession must be decided by geological monuments.

Successive Extinction of Species consistent with their limited Geographical Distribution.

In the preceding chapters I have pointed out the strict dependence of each species of animal and plant on certain physical conditions in the state of the earth's surface, and on the number and attributes of other organic beings inhabiting the same region. I have also endeavoured to show that all these conditions are in a state of continual fluctuation, the igneous and aqueous agents remodelling, from time to time, the physical geography of the globe, and the migrations of species causing new relations to spring up successively between different organic beings. I have deduced as a corollary, that the species existing at any particular period must, in the course of ages, become

extinct one after the other. "They must die out," to borrow an emphatical expression from Buffon; "because Time fights against them."

If the views which I have taken are just, there will be no difficulty in explaining why the habitations of so many species are now restrained within exceedingly narrow limits. Every local revolution, such as those contemplated in the preceding chapter, tends to circumscribe the range of some species, while it enlarges that of others; and if we are led to infer that new species originate in one spot only, each must require time to diffuse itself over a wide area. It will follow, therefore, from the adoption of this hypothesis, that the recent origin of some species, and the high antiquity of others, are equally consistent with the general fact of their limited distribution, some being local, because they have not existed long enough to admit of their wide dissemination; others, because circumstances in the animate or inanimate world have occurred to restrict the range which they may once have obtained.

As considerable modifications in the relative levels of land and sea have taken place in certain regions since the existing species were in being, we can feel no surprise that the zoologist and botanist have hitherto found it difficult to refer the geographical distribution of species to any clear and determinate principles, since they have usually speculated on the phenomena, upon the assumption that the physical geography of the globe had undergone no material alteration since the introduction of the species now living. So long as this assumption was made, the facts relating to the geography of plants and animals appeared capricious in the extreme, and by many the subject was pro-

nounced to be so full of mystery and anomalies, that the establishment of a satisfactory theory was hopeless.

Centres from which plants have been diffused. — Some botanists conceived, in accordance with the hypothesis of Willdenow, that mountains were the centres of creation from which the plants now inhabiting large continents have radiated ; to which De Candolle and others, with much reason, objected, that mountains, on the contrary, are often the barriers between two provinces of distinct vegetation. The geologist who is acquainted with the extensive modifications which the surface of the earth has undergone in very recent geological epochs, may be able, perhaps, to reconcile both these theories in their application to different regions.

A lofty range of mountains, which is so ancient as to date from a period when the species of animals and plants differed from those now living, will naturally form a barrier between contiguous provinces ; but a chain which has been raised, in great part, within the epoch of existing species, and around which new lands have arisen from the sea within that period, will be a centre of peculiar vegetation.

“ In France,” observes De Candolle, “ the Alps and Cevennes prevent a great number of the plants of the south from spreading themselves to the northward ; but it has been remarked that some species have made their way through the gorges of these chains, and are found on their northern sides, principally in those places where they are lower and more interrupted.” * Now the chains here alluded to have probably been of

* *Essai Élémentaire, &c., p. 46.*

considerable height ever since the era when the existing vegetation began to appear, and were it not for the deep fissures which divide them, they might have caused much more abrupt terminations to the extension of distinct assemblages of species.

Parts of the Italian peninsula, on the other hand, have gained a considerable portion of their present height, since a majority of the marine species now inhabiting the Mediterranean, and probably, also, since the terrestrial plants of the same region, were in being. Large tracts of land have been added, both on the Adriatic and Mediterranean side, to what originally constituted a much narrower range of mountains, if not a chain of islands running nearly north and south, like Corsica and Sardinia. It may therefore be presumed that the Apennines have been a centre whence species have diffused themselves over the contiguous *lower* and *newer* regions. In this and all analogous situations, the doctrine of Willdenow, that species have radiated from the mountains as from centres, may be well founded.

Introduction of New Species.

If the reader should infer, from the facts laid before him in the preceding chapters, that the successive extinction of animals and plants may be part of the constant and regular course of nature, he will naturally inquire whether there are any means provided for the repair of these losses? Is it part of the economy of our system that the habitable globe should, to a certain extent, become depopulated both in the ocean and on the land; or that the variety of species should diminish until some new era arrives when a new and extraordinary effort of creative energy is to be displayed?

Or is it possible that new species can be called into being from time to time, and yet that so astonishing a phenomenon can escape the observation of naturalists?

Humboldt has characterized these subjects as among the mysteries which natural science cannot reach; and he observes that the investigation of the origin of beings does not belong to zoological or botanical geography. To geology, however, these topics do strictly appertain; and this science is chiefly interested in inquiries into the state of the animate creation as it now exists, with a view of pointing out its relations to antecedent periods when its condition was different.

Before offering any hypothesis towards the solution of so difficult a problem, let us consider what kind of evidence we ought to expect, in the present state of science, of the first appearance of new animals or plants, if we could imagine the successive creation of species to constitute, like their gradual extinction, a regular part of the economy of nature.

In the first place, it is obviously more easy to prove that a species, once numerously represented in a given district, has ceased to be, than that some other which did not pre-exist has made its appearance — assuming always, for reasons before stated, that single stocks only of each animal and plant are originally created, and that individuals of new species do not suddenly start up in many different places at once.

So imperfect has the science of natural history remained down to our own times, that, within the memory of persons now living, the numbers of known animals and plants have been doubled, or even quadrupled, in many classes. New and often conspicuous species are annually discovered in parts of the old

continent, long inhabited by the most civilized nations. Conscious, therefore, of the limited extent of our information, we always infer, when such discoveries are made, that the beings in question had previously eluded our research ; or had at least existed elsewhere, and only migrated at a recent period into the territories where we now find them. It is difficult, even in contemplation, to anticipate the time when we shall be entitled to make any other hypothesis in regard to all the marine tribes, and to by far the greater number of the terrestrial ; — such as birds, which possess such unlimited powers of migration ; insects which, besides their numbers, are also so capable of being diffused to vast distances ; and cryptogamous plants, to which, as to many other classes, both of the animal and vegetable kingdom, similar observations are applicable.

What kind of evidence of new creations could be expected ? — What kind of proofs, therefore, could we reasonably expect to find of the origin at a particular period of a new species ?

Perhaps it may be said in reply that, within the last two or three centuries, some forest tree or new quadruped might have been observed to appear suddenly in those parts of England or France which had been most thoroughly investigated ; — that naturalists might have been able to show that no such living being inhabited any other region of the globe, and that there was no tradition of any thing similar having before been observed in the district where it had made its appearance.

Now, although this objection may seem plausible, yet its force will be found to depend entirely on the rate of fluctuation which we suppose to prevail in the animate world, and on the proportion which such con-

spicuous subjects of the animal and vegetable kingdoms bear to those which are less known and escape our observation. There are perhaps more than a million species of plants and animals, exclusive of the microscopic and infusory animalcules, now inhabiting the terraqueous globe. The terrestrial plants may amount, says De Candolle, to somewhere between 110,000 and 120,000* ; but the data on which this conjecture is founded are considered by many botanists to be vague and unsatisfactory. Sprengel only enumerated, in 1827, about 31,000 known phænogamous, and 6000 cryptogamous plants ; but that naturalist omitted many, perhaps 7000 phænogamous, and 1000 cryptogamous species. Mr. Lindley is of opinion that it would be rash, in the present state of science, to speculate on the existence of more than 80,000 phænogamous, and 10,000 cryptogamous plants. "If we take," he says, in a letter to the author on this subject, "37,000 as the number of published phænogamous species, and then add, for the undiscovered species in Asia and New Holland 15,000, in Africa 10,000, and in America 18,000, we have 80,000 species ; and if 7000 be the number of published cryptogamous plants, and we allow 3000 for the undiscovered species (making 10,000), there would then be, on the whole, 90,000 species."

It was supposed by Linnæus that there were four or five species of insects in the world for each phænogamous plant : but if we may judge from the relative proportion of the two classes in Great Britain, the number of insects must be still greater ; for the total number of British insects, "according to the last

* Géog. des Plantes. Dict. des Sci.

census," is about 12,500*, whereas there are only 1500 phænogamous plants indigenous to our island. As the insects are much more numerous in hot countries than in our temperate latitudes, it seems difficult to avoid the conclusion that there are more than half a million species in the world.

The number of known mammifers, according to Temminck, exceeds 800, and Baron Cuvier estimated the amount of known fishes at 6000. Nearly 6000 species of birds have likewise been ascertained.† We have still to add the reptiles, and all the invertebrated animals, exclusive of insects. It remains, in a great degree, mere matter of conjecture what proportion the aquatic tribes may bear to the denizens of the land ; but the habitable surface beneath the waters can hardly be estimated at less than double that of the continents and islands, even admitting that a very considerable area is destitute of life, in consequence of great depth, cold, darkness, and other circumstances. In the late polar expedition it was found that, in some regions, as in Baffin's Bay, there were marine animals inhabiting the bottom at great depths, where the temperature of the water was below the freezing point. That there is life at much greater profundities in warmer regions, may be confidently inferred. I have before stated that marine plants not only exist, but acquire vivid colours at depths where, to our senses, there would be darkness deep as night.

The ocean teems with life—the class of *polyps* alone are conjectured by Lamarck to be as strong in individuals as insects. Every tropical reef is described as covered with corals and sponges, and swarming with

* See Catalogue of Brit. Insects, by John Curtis, Esq.

† See Quarterly Review, No. xciv. p. 337.

crustacea, echini, and testacea ; while almost every tide-washed rock in the world is carpeted with fuci, and supports some corallines, actiniae, and mollusca. There are innumerable forms in the seas of the warmer zones, which have scarcely begun to attract the attention of the naturalist ; and there are parasitic animals without number, three or four of which are sometimes appropriated to one genus, as to the *Balena*, for example. Even though we concede, therefore, that the geographical range of marine species is more extensive in general than that of the terrestrial (the temperature of the sea being more uniform, and the land impeding less the migrations of the oceanic than the ocean those of the terrestrial species), yet it seems probable that the aquatic tribes far exceed in number the inhabitants of the land.

Without insisting on this point, it may be safe to assume, that, exclusive of microscopic beings, there are between one and two millions of species now inhabiting the terraqueous globe ; so that if only one of these were to become extinct annually, and one new one were to be every year called into being, much more than a million of years might be required to bring about a complete revolution in organic life.

I am not hazarding at present any hypothesis as to the probable rate of change ; but none will deny that when the *annual* birth and the *annual* death of one species on the globe is proposed as a mere speculation, this at least is to imagine no slight degree of instability in the animate creation. If we divide the surface of the earth into twenty regions of equal area, one of these might comprehend a space of land and water about equal in dimensions to Europe, and might contain a twentieth part of the million of species which,

may be assumed to exist in the animal kingdom. In this region one species only would, according to the rate of mortality before assumed, perish in twenty years, or only five out of fifty thousand in the course of a century. But as a considerable proportion of the whole would belong to the aquatic classes, with which we have a very imperfect acquaintance, we must exclude them from our consideration ; and if they constitute half of the entire number, then one species only might be lost in forty years among the terrestrial tribes. Now the mammalia, whether terrestrial or aquatic, bear so small a proportion to other classes of animals, forming less, perhaps, than one thousandth part of the whole, that if the longevity of species in the different orders were equal, a vast period must elapse before it would come to the turn of this conspicuous class to lose one of their number. If one species only of the whole animal kingdom died out in forty years, no more than one mammifer might disappear in 40,000 years, in a region of the dimensions of Europe.

It is easy, therefore, to see, that, in a small portion of such an area, in countries, for example, of the size of England and France, periods of much greater duration must elapse before it would be possible to authenticate the first appearance of one of the larger plants and animals, assuming the annual birth and death of one species to be the rate of vicissitude in the animate creation throughout the world.

The observations of naturalists, upon living species, may, in the course of future centuries, accumulate positive data, from which an insight into the laws which govern this part of our terrestrial system may be derived ; but, in the present deficiency of historical

records, we have traced up the subject to that point where geological monuments alone are capable of leading us on to the discovery of ulterior truths. To these, therefore, we must now appeal, carefully examining the strata of recent formation wherein the remains of *living* species, both animal and vegetable, are known to occur. We must study these strata in strict reference to their chronological order, as deduced from their superposition, and other relations. From these sources we may learn which of the species, now our contemporaries, have survived the greatest revolutions of the earth's surface; which of them have co-existed with the greatest number of animals and plants now extinct, and which have made their appearance only when the animate world had nearly attained its present condition.

From such data we may be enabled to infer, whether species have been called into existence in succession, or all at one period; whether singly, or by groups simultaneously; whether the antiquity of man be as high as that of any of the inferior beings which now share the planet with him, or whether the human species is one of the most recent of the whole.

To some of these questions we can even now return a satisfactory answer; and with regard to the rest, we have some data to guide conjecture, and to enable us to speculate with advantage: but in order to be fully qualified to enter upon such discussions the reader must study the ample body of materials amassed by the industry of modern geologists.

CHAPTER XII.

EFFECTS PRODUCED BY THE POWERS OF VITALITY ON THE STATE OF THE EARTH'S SURFACE.

Modifications in physical geography caused by organic beings — Why the vegetable soil does not augment in thickness — The theory, that vegetation is an antagonist power counterbalancing the degradation caused by running water untenable — Conservative influence of vegetation — Rain diminished by felling of forests — Distribution of American forests dependent on direction of predominant winds — Influence of man in modifying the physical geography of the globe.

THE second branch of our inquiry, respecting changes of the organic world, relates to the processes by which the remains of animals and plants become fossil, or, to speak still more generally, to all the effects produced by the powers of vitality on the surface and shell of the earth.

Before entering on the principal division of this subject, the imbedding and preservation of animal and vegetable remains, I shall offer a few remarks on the superficial modifications caused directly by the agency of organic beings, as when the growth of certain plants covers the slope of a mountain with peat, or converts a swamp into dry land ; or when vegetation prevents the soil, in certain localities, from being washed away by running water.

In considering alterations of this kind, brought about

in the physical geography of particular tracts, we are too apt to think exclusively of that part of the earth's surface which has emerged from beneath the waters, and with which alone, as terrestrial beings, we are familiar. Here the direct power of animals and plants to cause any important variation is, of necessity, very limited, except in checking the progress of that decay of which the land is the chief theatre. But if we extend our views, and, instead of contemplating the dry land, consider that larger portion which is assigned to the aquatic tribes, we discover the great influence of the living creation, in imparting varieties of conformation to the solid exterior which the agency of inanimate causes alone could not produce.

Thus, when timber is floated into the sea, it is often drifted to vast distances, and subsides in spots where there might have been no deposit, at that time and place, if the earth had not been tenanted by living beings. If, therefore, in the course of ages, a hill of wood, or lignite, be thus formed in the subaqueous regions, a change in the submarine geography may be said to have resulted from the action of organic powers. So in regard to the growth of coral reefs; it is probable that almost all the matter of which they are composed is supplied by mineral springs, which often rise up at the bottom of the sea, and which, on land, abound throughout volcanic regions hundreds of leagues in extent. The matter thus constantly given out could not go on accumulating for ever in the waters, but would be precipitated in the abysses of the sea, even if there were no polyps and testacea; but these animals arrest and secrete the carbonate of lime on the summits of submarine mountains, and form reefs many hundred feet in thickness, and hundreds of

miles in length, where, but for them, none might ever have existed.

Why the vegetable soil does not augment in thickness. — If no such voluminous masses are formed on the land, it is not from the want of solid matter in the structure of terrestrial animals and plants; but merely because, as I have so often stated, the continents are those parts of the globe where accessions of matter can scarcely ever take place — where, on the contrary, the most solid parts already formed are, each in their turn, exposed to gradual degradation. The quantity of timber and vegetable matter which grows in a tropical forest in the course of a century is enormous, and multitudes of animal skeletons are scattered there during the same period, besides innumerable land-shells and other organic substances. The aggregate of these materials, therefore, might constitute a mass greater in volume than that which is produced in any coral-reef during the same lapse of years; but, although this process should continue on the land for ever, no mountains of wood or bone would be seen stretching far and wide over the country, or pushing out bold promontories into the sea. The whole solid mass is either devoured by animals, or decomposes, as does a portion of the rock and soil on which the animals and plants are supported.

The waste of the strata themselves, accompanied by the decomposition of their organic remains, and the setting free of their alkaline ingredients, is one source from whence running water and the atmosphere may derive the materials which are absorbed by the roots and leaves of plants. Another source is the passage into a gaseous form of even the hardest parts of animals and plants which die and putrefy in the air,

where they are soon resolved into the elements of which they are composed; and while a portion of these constituents is volatilized, the rest is taken up by rain-water, and sinks into the earth, or flows towards the sea; so that they enter again and again into the composition of different organic beings.

The principal elements found in plants are hydrogen, carbon, and oxygen; so that water and the atmosphere contain all of them, either in their own composition or in solution.* The constant supply of these elements is maintained not only by the putrefaction of animal and vegetable substances, and the decay of rocks, but also by the copious evolution of carbonic acid and other gases from volcanos and mineral springs, and by the effects of ordinary evaporation, whereby aqueous vapours are made to rise from the ocean, and to circulate round the globe.

It is well known that, when two gases of different specific gravity are brought into contact, even though the heavier be the lowermost, they soon become uniformly diffused by mutual absorption through the whole space which they occupy. By virtue of this law, the heavy carbonic acid finds its way upwards through the lighter air of the atmosphere, and conveys nourishment to the lichen which covers the mountain top.

The fact, therefore, that the vegetable mould which covers the earth's surface does not decrease in thickness, will not altogether bear out the argument which was founded upon it by Playfair. This vegetable soil, he observes, consists partly of loose earthy materials,

* See some good remarks on the Formation of Soils, Baskerville's Geology, chap. xviii.

easily removed, in the form of sand and gravel ; partly of finer particles, suspended in the waters, which tinge those of some rivers continually, and those of all occasionally, when they are flooded. "The soil," he supposes, "although continually diminished from this cause, remains the same in quantity, or at least nearly the same, and must have done so ever since the earth was the receptacle of animal or vegetable life. The soil, therefore, is augmented from other causes, just as much, at an average, as it is diminished by that now mentioned ; and this augmentation evidently can proceed from nothing but the constant and slow disintegration of the rocks." *

That the repair of the *earthy* portion of the soil can proceed, as Playfair suggests, only from the decomposition of rocks, may be admitted ; but the *vegetable* matter may be supplied, and is actually furnished, in a great degree, by the absorption by plants of carbon and oxygen from the atmosphere ; so that in level situations, such as in platforms that intervene between valleys where the action of running water is very trifling, the vegetable particles carried off by the rain may be perpetually restored, not by the waste of the rock below, but from the air above.

If the quantity of food consumed by terrestrial animals, and the elements imbibed by the roots and leaves of plants were derived entirely from that supply of hydrogen, carbon, oxygen, azote, and other elements, given out into the atmosphere and the waters by the putrescence of organic substances, then we might imagine that the vegetable mould would, after a series of years, neither gain nor lose a single

* Illust. of Hutt. Theory, § 103.

particle by the action of organic beings ; and this conclusion is not far from the truth ; but the operation which renovates the vegetable and animal mould is by no means so simple as that here supposed. Thousands of carcasses of terrestrial animals are floated down, every century, into the sea ; and, together with forests of drift-timber, are imbedded in subaqueous deposits, where their elements are imprisoned in solid strata, and may there remain throughout whole geological epochs before they again become subservient to the purposes of life.

On the other hand, fresh supplies are derived by the atmosphere, and by running water, as before stated, from the disintegration of rocks and their organic contents, and through the agency of mineral springs from the interior of the earth, from whence all the elements before mentioned, which enter principally into the composition of animals and vegetables, are continually evolved. Even nitrogen has been recently found, by Dr. Daubeny, to be contained very generally in the waters of mineral springs.

Vegetation not an antagonist power counterbalancing the action of running water. — If we suppose that the copious supply from the nether regions, by springs and volcanic vents, of carbonic acid and other gases, together with the decomposition of rocks, may be just sufficient to counterbalance that loss of matter which, having already served for the nourishment of animals and plants, is annually carried down in organized forms, and buried in subaqueous strata, we concede the utmost that is consistent with probability. An opinion, however, has been expressed, that the processes of vegetable life, by absorbing various gases from the atmosphere, cause so large a mass of solid

matter to accumulate on the surface of the land, that this mass alone may constitute a great counterpoise to all the matter transported to lower levels by the aqueous agents of decay. Torrents and rivers, it is said — the waves of the sea and marine currents — act upon lines only ; but the power of vegetation to absorb the elastic and non-elastic fluids circulating round the earth, extends over the whole surface of the continents. By the silent but universal action of this great antagonist power, the spoliation and waste caused by running water on the land, and by the movements of the ocean, are neutralized, and even counterbalanced.*

In opposition to these views, I conceive that we shall form a juster estimate of the influence of vegetation, if we consider it as being in a slight degree conservative, and capable of retarding the waste of land, but not of acting as an antagonist power. The vegetable mould is seldom more than a few feet in thickness, and frequently does not exceed a few inches ; and we by no means find that its volume is more considerable on those parts of our continents which we can prove, by geological data, to have been elevated at more ancient periods, and where, consequently, there has been the greatest time for the accumulation of vegetable matter, produced throughout successive zoological epochs. On the contrary, these higher and older regions are more frequently denuded, so as to expose the bare rock to the action of the sun and air.

We find in the torrid zone, where the growth of plants is most rank and luxurious, that accessions of

* See Professor Sedgwick's Address to the Geological Society on the Anniversary, Feb. 1831, p. 24.

matter due to their agency are by no means the most conspicuous. Indeed it is in these latitudes, where the vegetation is most active, that for reasons to be explained in the next chapter, even those superficial peat mosses are unknown which cover a large area in some parts of our temperate zone. If the operation of animal and vegetable life could restore to the general surface of the continents a portion of the elements of those disintegrated rocks, of which such enormous masses are swept down annually into the sea, the effects would long ere this have constituted one of the most striking features in the structure and composition of our continents. All the great steppes and table-lands of the world, where the action of running water is feeble, would have become the grand repositories of organic matter, accumulated without that intermixture of earthy sediment which so generally characterizes the subaqueous strata.

Even the formation of peat in certain districts where the climate is cold and moist has not, in every instance, a conservative tendency. A peat-moss often acts like a vast sponge, absorbing water in large quantities, and swelling to the height of many yards above the surrounding country. In that case the turfy covering of the bog serves, like the skin of a bladder, to retain for a while the fluid within; and when that skin bursts, as has often happened in Ireland, and many parts of the continent, a violent inundation ensues. Examples will be mentioned in the next chapter, where the muddy torrent has hollowed out ravines, and borne along rocks and sand, in countries where such ravages could not have happened but for the existence of peat.

I may explain more clearly the kind of force which

I imagine vegetation to exert, by comparing it to the action of frost, which augments the height of some few alpine summits, by causing masses of perpetual snow to accumulate upon them, or fills up some valleys with glaciers ; but although by this process of conge-lation the rain-water that has risen by evaporation from the sea is retained for a while in a solid form upon the land, and though some elevated spots may be protected from waste by a constant covering of ice, yet, on the other hand, the sudden melting of snow often accelerates the degradation of rock. Although every year fresh snow and ice are formed, as also more vegetable and animal matter, yet there is no increase; the one melts, the other putrefies, or is drifted down to the sea by rivers. If this were not the case, frost might be considered as an antagonist power, as well as the action of animal and vegetable life.

I have already stated that, in the known operation of the *igneous* causes, a real antagonist power is found, which may counterbalance the levelling action of run-ning water* ; and there seems no good reason for presuming that the upheaving and depressing force of earthquakes, together with the ejection of matter by volcanos, may not be fully adequate to restore that inequality of the surface which rivers and the waves and currents of the ocean annually tend to lessen. If a counterpoise be derived from this source, the quan-tity and elevation of land above the sea may for ever remain the same, in spite of the action of the aqueous causes, which, if thus counteracted, may never be able to reduce the surface of the earth more nearly to a state of equilibrium than that which it has now at-

* Book II. chap. i. ; Vol. II. p. 475.

tained ; and, on the other hand, the force of the aqueous agents themselves might thus continue for ever unimpaired. This permanence of the average intensity of the powers now in operation would account for any amount of disturbance or degradation of the earth's crust, so far as the *mere quantity* of movement or decay is concerned ; provided only that indefinite periods of time are contemplated.

As to the intensity of the disturbing causes at particular epochs, their effects have as yet been studied for too short a time to enable us fully to compare the signs of ancient convulsions with the permanent monuments left in the earth's crust by the events of the last few thousand years. But, notwithstanding the small number of changes which have been witnessed and carefully recorded, observation has at least shown that our knowledge of the extent of the subterranean agency, as now developed from time to time, is in its infancy ; and there can be no doubt that great partial alterations in the structure of the earth's crust are brought about in volcanic regions, without any interruption to the general tranquillity of the habitable surface.

Conservative influence of vegetation. — If, then, vegetation cannot act as an antagonist power amid the mighty agents of change which are always modifying the surface of the globe, let us next inquire how far its influence is conservative, — how far it may retard the levelling effects of running water, which it cannot oppose, much less counterbalance.

It is well known that a covering of herbage and shrubs may protect a loose soil from being carried away by rain, or even by the ordinary action of a river, and may prevent hills of loose sand from being blown

away by the wind; for the roots bind together the separate particles into a firm mass, and the leaves intercept the rain-water, so that it dries up gradually, instead of flowing off in a mass and with great velocity. The old Italian hydrographers make frequent mention of the increased degradation which has followed the clearing away of natural woods in several parts of Italy. A remarkable example was afforded in the Upper Val d'Arno, in Tuscany, on the removal of the woods clothing the steep declivities of the hills by which that valley is bounded. When the ancient forest laws were abolished by the Grand Duke Joseph, during the last century, a considerable tract of surface in the Cassentina (the Clausentium of the Romans) was denuded, and immediately the quantity of sand and soil washed down into the Arno increased enormously. Frisi, alluding to such occurrences, observes, that as soon as the bushes and plants were removed, the waters flowed off more rapidly, and, in the manner of floods, swept away the vegetable soil.*

This effect of vegetation is of high interest to the geologist, when he is considering the formation of those valleys which have been principally due to the action of rivers. The spaces intervening between valleys, whether they be flat or ridgy, when covered with vegetation, may scarcely undergo the slightest waste, as the surface may be protected by the green sward of grass; and this may be renewed, in the manner before described, from elements derived from rain-water and the atmosphere. Hence, while the river is continually bearing down matter in the alluvial plain, and undermining the cliffs on each side of every valley,

* Treatise on Rivers and Torrents, p. 5. Garston's translation.

the height of the intervening rising grounds may remain stationary.

In this manner, a cone of loose scoriæ, sand, and ashes, such as Monte Nuovo, may, when it has once become densely clothed with herbage and shrubs, suffer scarcely any further dilapidation; and the perfect state of the cones of hundreds of extinct volcanos in France, Campania, Sicily, and elsewhere, may prove nothing whatever, either as to their relative or absolute antiquity. We may be enabled to infer, from the integrity of such conical hills of incoherent materials, that no flood can have passed over the countries where they are situated, since their formation; but the atmospheric action alone, in spots where there happen to be no torrents, and where the surface was clothed with vegetation, could scarcely in any lapse of ages have destroyed them.

During a tour in Spain, in 1830, I was surprized to see a district of gently undulating ground in Catalonia, consisting of red and grey sandstone, and in some parts of red marl, almost entirely denuded of herbage; while the roots of the pines, holm oaks, and some other trees, were half exposed, as if the soil had been washed away by a flood. Such is the state of the forests, for example, between Oristo and Vich, and near San Lorenzo. But, being overtaken by a violent thunder-storm, in the month of August, I saw the whole surface, even the highest levels of some flat-topped hills, streaming with mud, while on every declivity the devastation of torrents was terrific. The peculiarities in the physiognomy of the district were at once explained; and I was taught that, in speculating on the greater effects which the direct action of rain may once have produced on the surface of certain parts

of England, we need not revert to periods when the heat of the climate was *tropical*.

In the torrid zone the degradation of land is generally more rapid ; but the waste is by no means proportioned to the superior quantity of rain or the suddenness of its fall, the transporting power of water being counteracted by a greater luxuriance of vegetation. A geologist who is no stranger to tropical countries observes, that the softer rocks would speedily be washed away in such regions, if the numerous roots of plants were not matted together in such a manner as to produce considerable resistance to the destructive power of the rains. The parasitical and creeping plants also entwine in every possible direction, so as to render the forests nearly impervious, and the trees possess forms and leaves best calculated to shoot off the heavy rains ; which, when they have thus been broken in their fall, are quickly absorbed by the ground beneath, or, when thrown into the drainage depressions, give rise to furious torrents.*

Influence of Man in modifying the Physical Geography of the Globe.

Before concluding this chapter, I shall offer a few observations on the influence of man in modifying the physical geography of the globe ; for we must class his agency among the powers of organic nature.

Felling of forests. — The felling of forests has been attended, in many countries, by a diminution of rain, as in Barbadoes and Jamaica.† For in tropical countries, where the quantity of aqueous vapour in the atmosphere is great, but where, on the other hand, the

* De la Beche, Geol. Man., p. 184 first ed.

† Phil. Trans., vol. ii. p. 294.

direct rays of the sun are most powerful, any impediment to the free circulation of air, or any screen which shades the earth from the solar rays, becomes a source of humidity; and wherever dampness and cold have begun to be generated by such causes, the condensation of vapour continues. The leaves, moreover, of all plants are alembics, and some of those in the torrid zone have the remarkable property of distilling water, thus contributing to prevent the earth from becoming parched up.

Distribution of the American forests. — There can be no doubt, then, that the state of the climate, especially the humidity of the atmosphere, influences vegetation, and that, in its turn, vegetation re-acts upon the climate; but some writers seem to have attributed too much importance to the influence of forests, particularly those of America, as if they were the primary cause of the moisture of the climate.

The theory of a modern author on this subject "that forests exist in those parts of America only where the predominant winds carry with them a considerable quantity of moisture from the ocean," seems far more rational. In all countries, he says, "having a summer heat exceeding 70°, the presence or absence of natural woods, and their greater or less luxuriance, may be taken as a measure of the amount of humidity, and of the fertility of the soil. Short and heavy rains, in a warm country, will produce grass, which, having its roots near the surface, springs up in a few days, and withers when the moisture is exhausted; but transitory rains, however heavy, will not nourish trees; because, after the surface is saturated with water, the rest runs off, and the moisture lodged in the soil neither sinks deep enough, nor is in sufficient quantity

to furnish the giants of the forest with the necessary sustenance. It may be assumed that twenty inches of rain falling moderately, or at intervals, will leave a greater permanent supply in the soil than forty inches falling, as it sometimes does in the torrid zone, in as many hours.”*

“ In all regions,” he continues, “ where ranges of mountains intercept the course of the constant or predominant winds, the country on the windward side of the mountains will be moist, and that on the leeward dry; and hence parched deserts will generally be found on the west side of countries within the tropics, and on the east side of those beyond them, the prevailing winds in these cases being generally in opposite directions. On this principle, the position of forests in North and South America may be explained. Thus, for example, in the region within the thirtieth parallel, the moisture swept up by the trade-wind from the Atlantic is precipitated in part upon the mountains of Brazil, which are but low, and so distributed as to extend far into the interior. The portion which remains is borne westward, and, losing a little as it proceeds, is at length arrested by the Andes, where it falls down in showers on their summits. The aerial current, now deprived of all the humidity with which it can part, arrives in a state of complete exsiccation at Peru, where, consequently, no rain falls. In the same manner the Ghauts in Hindostan, a chain only three or four thousand feet high, intercept the whole moisture of the atmosphere, having copious rains on their windward side, while on the other the weather remains clear and dry. The rains in this case change regularly from the

* Maclaren, art. *America*, Encyc. Britannica.

west side to the east, and vice versa, *with the monsoons*. But in the region of America, beyond the thirtieth parallel, the Andes serve as a screen to intercept the moisture brought by the prevailing winds from the Pacific Ocean : rains are copious on their summits, and in Chili on their *western* declivities ; but none falls on the plains to the *eastward*, except occasionally when the wind blows from the Atlantic." *

I have been more particular in explaining these views, because they appear to place in a true light the dependence of vegetation on climate, the humidity being increased, and more uniformly diffused throughout the year, by the gradual spreading of wood.

It has been affirmed, that formerly, when France and England were covered with wood, Europe was much colder than at present ; that the winters in Italy were longer, and that the Seine, and many other rivers, froze more regularly every winter than now. M. Arago, in a recent essay on this subject, has endeavoured to show, by tables of observations on the congelation of the Rhine, Danube, Rhone, Po, Seine, and other rivers, at different periods, that there is no reason to believe the cold to have been in general more intense in ancient times. † He admits, however, that the climate of Tuscany has been so far modified, by the removal of wood, as that the winters are less cold ; but the summers also, he contends, are less hot than of old ; and the summers, according to him, were formerly hotter in France than in our own times. His evidence is derived chiefly from documents show-

* Maclaren, art. America, Encyc. Britannica, where the position of the American forests, in accordance with this theory, is laid down in a map.

† Annuaire du Bureau des Long. 1834.

ing that wine was made three centuries ago in the Vivarais and several other provinces, at an earlier season, at greater elevations, and in higher latitudes, than are now found suitable to the vine.

In the United States of North America it is unquestionable that the rapid *clearing* of the country has rendered the winters less severe and the summers less hot; in other words, the extreme temperatures of January and July have been observed from year to year to approach nearer to each other. Whether in this case, or in France, the *mean* temperature has been raised, seems by no means as yet decided; but there is no doubt that the climate has become, as Buffon would have said, "less excessive."

The modifications of the surface, resulting from human agency, are only great when we have obtained so much knowledge of the working of the laws of nature as to be enabled to use them as powerful instruments to effect our purposes. We command nature, according to the saying of the philosopher, by obeying her laws; and for this reason we can never materially interfere with any of the great changes which either the aqueous or igneous causes are bringing about on the earth. In vain would the inhabitants of Italy strive to prevent the tributaries of the Po and Adige from bearing down, annually, an immense volume of sand and mud from the Alps and Apennines; in vain would they toil to reconvey to the mountains the mass torn from them year by year, and deposited in the form of sediment in the Adriatic. Yet they have been able to vary the distribution of this sediment over a considerable area, by embanking the rivers, and preventing the sand and mud from being spread by annual inundations over the plains.

I have explained how the form of the delta of the Po has been altered by this system of embankment, and how much more rapid have been the accessions of land at the mouths of the Po and Adige within the last twenty centuries. There is a limit; however, to these modifications, since the danger of floods augments with the increasing height of the river-beds; while the expense of maintaining the barrier is continually enhanced, as well as the difficulty of draining the low surrounding country. "In the Ganges," says Major R. H. Colebrooke, "no sooner is a slight covering of soil observed on a new sand-bank than the island is cultivated; water-melons, cucumbers, and mustard, become the produce of the first year; and rice is often seen growing near the water's edge, where the mud is in large quantity. Such islands may be swept away before they have acquired a sufficient degree of stability to resist permanently the force of the stream; but if, by repeated additions of soil, they acquire height and firmness, the natives take possession, and bring over their families, cattle, and effects. They choose the highest spots for the sites of villages, where they erect their dwellings with as much confidence as they would do on the main land; for, although the foundation is sandy, the uppermost soil, being interwoven with the roots of grass and other plants, and hardened by the sun, is capable of withstanding all attacks of the river. These islands often grow to a considerable size, and endure for the lives of the new possessors, being only at last destroyed by the same gradual process of undermining and encroachment to which the banks of the Ganges are subject." *

* Asiatic Trans., vol. vii.

If Bengal were inhabited by a nation more advanced in opulence and agricultural skill, they might, perhaps, succeed in defending these possessions against the ravages of the stream for much longer periods ; but no human power could ever prevent the Ganges or the Mississippi from making and unmaking islands. By fortifying one spot against the set of the current, its force is only diverted against some other point ; and, after a vast expense of time and labour, the property of individuals may be saved, but no addition would thus be made to the sum of productive land. It may be doubted whether any system could be devised so conducive to *national* wealth as the simple plan pursued by the peasants of Hindostan, who, wasting no strength in attempts to thwart one of the great operations of nature, permit the alluvial surface to be perpetually renovated, and find their losses in one place compensated in some other, so that they continue to reap an undiminished harvest from a virgin soil.

To the geologist the Gangetic islands and their migratory colonies may present an epitome of the globe as tenanted by man ; for during every century we cede some territory which the earthquake has sunk, or the volcano has covered by its fiery products, or which the ocean has devoured by its waves. On the other hand, we gain possession of new lands, which rivers, tides, or volcanic ejections have formed, or which subterranean causes have upheaved from the deep. Whether the human species will outlast the whole or a great part of the continents and islands now seen above the waters, is a question far beyond the reach of our conjectures ; but thus much may be inferred from geological data, — that if such should be its fate, it will be no more than has already been the lot of

pre-existing species, some of which have, ere now, outlived the form and distribution of land and sea which prevailed at the era of their birth.

I have before shown, when treating of the excavation of new estuaries in Holland by inroads of the ocean, as also of the changes on our own coasts, that although the conversion of sea into land by artificial labours may be great, yet it must always be in subordination to the great movements of the tides and currents.* If, in addition to the assistance obtained by parliamentary grants for defending Dunwich from the waves, all the resources of Europe had been directed to the same end, the existence of that port might possibly have been prolonged for many centuries.† But, in the mean time, the current would have continued to sweep away portions from the adjoining cliffs on each side, rounding off the whole line of coast into its present form, until at length the town, projecting as a narrow promontory, must have become exposed to the irresistible fury of the waves.

It is scarcely necessary to observe, that the control which man can obtain over the igneous agents is less even than that which he may exert over the aqueous. He cannot modify the upheaving or depressing force of earthquakes, or the periods or degree of violence of volcanic eruptions; and on these causes the inequalities of the earth's surface, and, consequently, the shape of the sea and land, appear mainly to depend. The utmost that man can hope to effect in this respect is occasionally to divert the course of a lava stream, and to prevent the burning matter, for a season, from overwhelming a city, or some other of the proudest works of human industry.

* Book II. chap. viii.

† Vol. II. p. 58.

No application, perhaps, of human skill and labour tends so greatly to vary the state of the habitable surface, as that employed in the drainage of lakes and marshes, since not only the *stations* of many animals and plants, but the general climate of a district, may thus be modified. It is also a kind of alteration to which it is difficult to find any thing analogous in the agency of inferior beings ; for we ought always, before we decide that any part of the influence of man is novel and anomalous, carefully to consider the powers of all other animated agents which may be limited or superseded by him. Many who have reasoned on these subjects seem to have forgotten that the human race often succeeds to the discharge of functions previously fulfilled by other species ; a topic on which I have already offered some hints, when explaining how the distribution and numbers of each species are dependent on the state of contemporary beings.

Suppose the growth of some of the larger terrestrial plants, or, in other words, the extent of forests, to be diminished by man, and the climate to be thereby modified, it does not follow that this kind of innovation is unprecedented. It is a change in the state of vegetation, and such may often have been the result of the appearance of new species upon the earth. The multiplication, for example, of certain insects in parts of Germany, during the last century, destroyed more trees than man, perhaps, could have felled during an equal period.

It would be rash, however, to pretend to decide how far the power of man to modify the surface may differ in kind or degree from that of other living beings; the problem is certainly more complex than

many who have speculated on such topics have imagined. If land be raised from the sea, the greatest alteration in its physical condition, which could ever arise from the influence of organic beings, would probably be produced by the first immigration of terrestrial plants, whereby the new tract would become covered with vegetation. The change next in importance would seem to be when animals first enter, and modify the proportionate numbers of certain species of plants. If there be any anomaly in the intervention of man, in farther varying the relative numbers in the vegetable kingdom, it may not so much consist in the kind or absolute quantity of alteration, as in the circumstance that a *single species*, in this case, would exert, by its superior power and universal distribution, an influence equal to that of hundreds of other terrestrial animals.

If we inquire whether man, by his direct power, or by the changes which he may give rise to indirectly, tends, upon the whole, to lessen or increase the inequalities of the earth's surface, we shall incline, perhaps, to the opinion that he is a levelling agent. In mining operations he conveys upwards a certain quantity of materials from the bowels of the earth; but, on the other hand, much rock is taken annually from the land, in the shape of ballast, and afterwards thrown into the sea, and by this means, in spite of prohibitory laws, many harbours, in various parts of the world, have been blocked up. We rarely transport heavy materials to higher levels, and our pyramids and cities are chiefly constructed of stone brought down from more elevated situations. By ploughing up thousands of square miles, and exposing a surface for part of the year to the action of the elements, we assist the

abrading force of rain, and diminish the conservative effects of vegetation.

But the aggregate force exerted by man is truly insignificant, when we consider the operations of the great physical agents, whether aqueous or igneous, of the inanimate world. If all the nations of the earth should attempt to quarry away the lava which flowed during one eruption from the Icelandic volcanos in 1783, and the two following years, and should attempt to consign it to the deepest abysses of the ocean, they might toil for thousands of years before their task was accomplished. Yet the matter borne down by the Ganges and Burrampooter, in a single year, probably very much exceeds, in weight and volume, the mass of Icelandic lava produced by that great eruption.*

* Vol. II. p. 13.

CHAPTER XIII.

INCLOSING OF FOSSILS IN PEAT, BLOWN SAND AND VOLCANIC EJECTIONS.

Division of the subject — Imbedding of organic remains in deposits on emerged land — Growth of peat — Site of ancient forests in Europe now occupied by peat — Bog iron-ore — Preservation of animal substances in peat — Miring of quadrupeds — Bursting of the Solway moss — Imbedding of organic bodies and human remains in blown sand — Moving sands of African deserts — De Luc on their recent origin — Buried temple of Ipsambul — Dried carcasses in the sands — Towns overwhelmed by sand-floods — Imbedding of organic and other remains in volcanic formations on the land.

Division of the subject. — THE next subject of inquiry is the mode in which the remains of animals and plants become fossil, or are buried in the earth by natural causes. M. Constant Prevost has observed, that the effects of geological causes are divisible into two great classes; those produced on the surface during the submersion of land beneath the waters, and those which take place after its emersion. Agreeably to this classification, I shall consider, first, in what manner animal and vegetable remains become included and preserved in deposits on emerged land, or that part of the surface which is not *permanently* covered by water, whether of seas or lakes; secondly, the manner in which organic remains become imbedded in subaqueous deposits.

Under the first division, I shall treat of the following topics :— 1st, the growth of peat, and the preservation of vegetable and animal remains therein ;— 2dly, the burying of organic remains in blown sand ;— 3dly, of the same in the ejections and alluviums of volcanos ;— 4thly, in alluviums generally, and in the ruins of landslips ;— 5thly, in the mud and stalagmite of caves and fissures.

Growth of Peat, and Preservation of Vegetable and Animal Remains therein.

The generation of peat, when not completely under water, is confined to moist situations, where the temperature is low, and where vegetables may decompose without putrefying. It may consist of any of the numerous plants which are capable of growing in such *stations* ; but a species of moss (*Sphagnum palustre*) constitutes a considerable part of the peat found in marshes of the north of Europe ; this plant having the property of throwing up new shoots in its upper part, while its lower extremities are decaying.* Reeds, rushes, and other aquatic plants may usually be traced in peat ; and their organization is often so entire that there is no difficulty in discriminating the distinct species.

Analysis of peat. — In general, says Sir H. Davy, one hundred parts of dry peat contain from sixty to ninety-nine parts of matter destructible by fire ; and the residuum consists of earths usually of the same kind as the substratum of clay, marl, gravel, or rock,

* For a catalogue of the plants which contribute to the generation of peat, see Dr. Rennie on Peat, pp. 171—178. ; and Dr. MacCulloch's Western Isles, vol. i. p. 129.

on which they are found, together with oxide of iron. "The peat of the chalk counties of England," observes the same writer, "contains much gypsum; but I have found very little in any specimens from Ireland or Scotland, and in general these peats contain very little saline matter."* From the researches of Dr. MacCulloch, it appears that peat is intermediate between simple vegetable matter and lignite, the conversion of peat to lignite being gradual, and being brought about by the prolonged action of water.†

Peat abundant in cold and humid climates.—Peat is sometimes formed on a declivity in mountainous regions, where there is much moisture; but in such situations it rarely, if ever, exceeds four feet in thickness. In bogs, and in low grounds into which alluvial peat is drifted, it is found forty feet thick, and upwards; but in such cases it generally owes one half of its volume to the water which it contains. It has seldom, if ever, been discovered within the tropics; and it rarely occurs in the valleys, even in the south of France and Spain. It abounds more and more, in proportion as we advance farther from the equator, and becomes not only more frequent but more inflammable in northern latitudes.‡

The same phenomenon is repeated in the southern hemisphere. No peat is found in Brazil, nor even in the swampy parts of the country drained by the La Plata on the east side of South America, or in the island of Chiloe on the west; yet when we reach the 45th degree of latitude and examine the Chonos

* Irish Bog Reports, p. 209.

† System of Geology, vol. ii. p. 353.

‡ Rev. Dr. Rennie on Peat, p. 260.

Archipelago or the Falkland Islands, and Terra del Fuego, we meet with an abundant growth of this substance. Almost all plants contribute here by their decay to the production of peat, even the grasses ; but it is a singular fact, says Mr. Darwin, as contrasted with what occurs in Europe, that no kind of moss enters into the composition of the South American peat, which is formed by many plants, but chiefly by that called by Brown, *Astelia pumila*.*

Extent of surface covered by peat.—There is a vast extent of surface in Europe covered with peat, which, in Ireland, is said to extend over a tenth of the whole island. One of the mosses on the Shannon is described by Dr. Boate to be fifty miles long, by two or three broad ; and the great marsh of Montoire, near the mouth of the Loire, is mentioned, by Blavier, as being more than fifty leagues in circumference. It is a curious and well-ascertained fact, that many of these mosses of the north of Europe occupy the place of forests of pine and oak, which have, many of them, disappeared within the historical era. Such changes are brought about by the fall of trees and the stagnation of water, caused by their trunks and branches obstructing the free drainage of the atmospheric waters, and giving rise to a marsh. In a warm climate, such decayed timber would immediately be removed by insects, or by putrefaction ; but, in the cold temperature now prevailing in our latitudes, many examples are recorded of marshes originating in this source. Thus, in Mar forest, in Aberdeenshire, large trunks of Scotch fir, which had fallen from age and decay, were soon immured in peat, formed partly out of their

* Darwin's Journal, p. 349.

perishing leaves and branches, and in part from the growth of other plants. We also learn, that the overthrow of a forest by a storm, about the middle of the seventeenth century, gave rise to a peat moss near Lochbroom, in Ross-shire, where, in less than half a century after the fall of the trees, the inhabitants dug peat.* Dr. Walker mentions a similar change, when, in the year 1756, the whole wood of Drumlanrig in Dumfries-shire was overset by the wind. Such events explain the occurrence, both in Britain and on the Continent, of mosses where the trees are all broken within two or three feet of the original surface, and where their trunks all lie in the same direction.†

It may however be suggested in these cases, that the soil had become exhausted for trees, and that, on the principle of that natural rotation which prevails in the vegetable world, one set of plants died out and another succeeded. It is certainly a remarkable fact that in the Danish islands, and in Jutland and Holstein, fir wood of various species, especially Scotch fir, is found at the bottom of the peat mosses, although it is well ascertained that for the last five centuries no coniferæ have grown wild in these countries; the coniferous trees which now flourish there having been all planted towards the close of the last century.

Nothing is more common than the occurrence of buried trees at the bottom of the Irish peat-mosses, as also in most of those of England, France, and Holland; and they have been so often observed with parts of their trunks standing erect, and with their roots fixed to the sub-soil, that no doubt can be entertained of their having generally grown on the spot. They consist,

* Dr. Rennie's Essays, p. 65.

† Ibid. p. 30.

for the most part, of the fir, the oak, and the birch : where the sub-soil is clay, the remains of oak are the most abundant ; where sand is the substratum, fir prevails. In the marsh of Curragh, in the Isle of Man, vast trees are discovered standing firm on their roots, though at the depth of eighteen or twenty feet below the surface. Some naturalists have desired to refer the imbedding of timber in peat-mosses to aqueous transportation, since rivers are well known to float wood into lakes ; but the facts above mentioned show that, in numerous instances, such an hypothesis is inadmissible. It has, moreover, been observed, that in Scotland, as also in many parts of the Continent, the largest trees are found in those peat-mosses which lie in the least elevated regions, and that the trees are proportionally smaller in those which lie at higher levels ; from which fact De Luc and Walker have both inferred, that the trees grew on the spot, for they would naturally attain a greater size in lower and warmer levels. The leaves also, and fruits of each species, are continually found immersed in the moss along with the parent trees ; as, for example, the leaves and acorns of the oak, the cones and leaves of the fir, and the nuts of the hazel.

Recent origin of some peat-mosses. — In Hatfield moss, in Yorkshire, which appears clearly to have been a forest eighteen hundred years ago, fir-trees have been found ninety feet long, and sold for masts and keels of ships ; oaks have also been discovered there above one hundred feet long. The dimensions of an oak from this moss are given in the Philosophical Transactions, No. 275., which must have been larger than any tree now existing in the British dominions.

In the same moss of Hatfield, as well as in that of

Kincardine, in Scotland, and several others, Roman roads have been found covered to the depth of eight feet by peat. All the coins, axes, arms, and other utensils found in British and French mosses, are also Roman ; so that a considerable portion of the European peat-bogs are evidently not more ancient than the age of Julius Cæsar. Nor can any vestiges of the ancient forests described by that general, along the line of the great Roman way in Britain, be discovered, except in the ruined trunks of trees in peat.

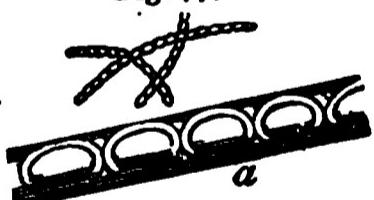
De Luc ascertained that the very site of the aboriginal forests of Hircinia, Semana, Ardennes, and several others, are now occupied by mosses and fens ; and a great part of these changes have, with much probability, been attributed to the strict orders given by Severus, and other emperors, to destroy all the wood in the conquered provinces. Several of the British forests, however, which are now mosses, were cut at different periods, by order of the English parliament, because they harboured wolves or outlaws. Thus the Welsh woods were cut and burnt, in the reign of Edward I.; as were many of those in Ireland, by Henry II., to prevent the natives from harbouring in them, and harassing his troops.

It is curious to reflect that considerable tracts have, by these accidents, been permanently sterilized, and that, during a period when civilization has been making great progress, large areas in Europe have, by human agency, been rendered less capable of administering to the wants of man. Rennie observes, with truth, that in those regions alone which the Roman eagle never reached — in the remote circles of the German empire, in Poland and Prussia, and still more in Norway, Sweden, and the vast empire of Russia — can we

see what Europe was before it yielded to the power of Rome.* Desolation now reigns where stately forests of pine and oak once flourished, such as might now have supplied all the navies of Europe with timber.

Sources of bog iron-ore. — At the bottom of peat-mosses there is sometimes found a cake, or "pan," as it is termed, of oxide of iron, and the frequency of bog iron-ore is familiar to the mineralogist. The oak, which is so often found dyed black in peat, owes its colour to the same metal. From what source the iron is derived has often been a subject of discussion, until the discoveries of Ehrenberg seem at length to have removed the difficulty. He had observed in the marshes about Berlin, a substance of a deep ochre yellow passing into red, which covered the bottom of the ditches, and which, where it had become dry after the evaporation of the water, appeared exactly like oxide of iron. But under the microscope it was found to consist of slender articulated threads, which are the shields partly siliceous and partly ferruginous of

Fig. 77.



Gaillonella ferruginea.
a. 2000 times magnified.

an infusory animalcule, called *Gaillonella ferruginea*. There can be little doubt, therefore, that bog iron-ore consists of an aggregate of millions of these infusorial shields invisible to the

naked eye.†

Preservation of animal substances in peat. — One interesting circumstance attending the history of peat-mosses is the high state of preservation of animal substances buried in them for periods of many years. In

* Essays, &c., p. 74.

† Ehrenberg, Taylor's Scientific Mem. vol. i. part iii. p. 402.

June, 1747, the body of a woman was found six feet deep, in a peat-moor in the Isle of Axholm, in Lincolnshire. The antique sandals on her feet afforded evidence of her having been buried there for many ages: yet her nails, hair, and skin, are described as having shown hardly any marks of decay. On the estate of the Earl of Moira, in Ireland, a human body was dug up, a foot deep in gravel, covered with eleven feet of moss; the body was completely clothed, and the garments seemed all to be made of hair. Before the use of wool was known in that country, the clothing of the inhabitants was made of hair, so that it would appear that this body had been buried at that early period; yet it was fresh and unimpaired.* In the Philosophical Transactions, we find an example recorded of the bodies of two persons having been buried in moist peat, in Derbyshire, in 1674, about a yard deep, which were examined twenty-eight years and nine months afterwards; “the colour of their skin was fair and natural, their flesh soft as that of persons newly dead.”†

Among other analogous facts we may mention, that in digging a pit for a well near Dulverton, in Somersetshire, many pigs were found in various postures, still entire. Their shape was well preserved, the skin, which retained the hair, having assumed a dry, membranous appearance. Their whole substance was converted into a white, friable, laminated, inodorous and tasteless substance; but which, when exposed to heat, emitted an odour precisely similar to broiled bacon.‡

* Dr. Rennie, *Essays, &c.*, p. 521., where several other instances are referred to.

† Phil. Trans., vol. xxxviii., 1734.

‡ Dr. Rennie, *Essays, &c.*, p. 521.

Cause of the antiseptic property of peat.—We naturally ask whence peat derives this antiseptic property? It has been attributed by some to the carbonic and gallic acids which issue from decayed wood, as also to the presence of charred wood in the lowest strata of many peat-mosses, for charcoal is a powerful antiseptic, and capable of purifying water already putrid. Vegetable gums and resins also may operate in the same way.*

The tannin occasionally present in peat is the produce, says Dr. Mac Culloch, of tormentilla, and some other plants; but the quantity he thinks too small, and its occurrence too casual, to give rise to effects of any importance. He hints that the soft parts of animal bodies, preserved in peat-bogs, may have been converted into adipocire by the action of water merely; an explanation which appears clearly applicable to some of the cases above enumerated.†

Miring of quadrupeds.—The manner, however, in which peat contributes to preserve, for indefinite periods, the harder parts of terrestrial animals, is a subject of more immediate interest to the geologist. There are two ways in which animals become occasionally buried in the peat of marshy grounds; they either sink down into the semifluid mud, underlying a turf surface, upon which they have rashly ventured, or, at other times, a bog “bursts,” in the manner before described, and animals may be involved in the peaty alluvium.‡

In the extensive bogs of Newfoundland cattle are sometimes found buried with only their heads and

* Dr. Rennie, *Essays, &c.*, p. 531.

† *Syst. of Geol.*, vol. ii. pp. 340—346.

‡ See above, p. 248.

neck above ground ; and after having remained for days in this situation, they have been drawn out by ropes and saved. In Scotland, also, cattle venturing on the “quaking moss” are often mired, or “laired,” as it is termed ; and in Ireland, Mr. King asserts that the number of cattle which are lost in sloughs is quite incredible.*

Solway moss.—The description given of the Solway moss will serve to illustrate the general character of these boggy grounds. That moss, observes Gilpin, is a flat area, about seven miles in circumference, situated on the western confines of England and Scotland. Its surface is covered with grass and rushes, presenting a dry crust and a fair appearance ; but it shakes under the least pressure, the bottom being unsound and semi-fluid. The adventurous passenger, therefore, who sometimes in dry seasons traverses this perilous waste, to save a few miles, picks his cautious way over the rushy tussocks as they appear before him, for here the soil is firmest. If his foot slip, or if he venture to desert this mark of security, it is possible he may never more be heard of.

“At the battle of Solway, in the time of Henry VIII. (1542), when the Scotch army, commanded by Oliver Sinclair, was routed, an unfortunate troop of horse, driven by their fears, plunged into this morass, which instantly closed upon them. The tale was traditional, but it is now authenticated ; a man and horse, in complete armour, having been found by peat-diggers, in the place where it was always supposed the affair had happened. The skeleton of each was well preserved, and the different parts of the armour easily distinguished.”†

* Phil. Trans., vol. xv. p. 949.

† Gilpin, Observ. on Picturesque Beauty, &c., 1772.

This same moss, on the 16th of December, 1772, having been filled with water during heavy rains, rose to an unusual height, and then burst. A stream of black half-consolidated mud began at first to creep over the plain, resembling, in the rate of its progress, an ordinary lava current. No lives were lost, but the deluge totally overwhelmed some cottages, and covered 400 acres. The highest parts of the original moss subsided to the depth of about twenty-five feet; and the height of the moss, on the lowest parts of the country which it invaded, was at least fifteen feet.

Bursting of a peat-moss in Ireland. — A recent inundation in Sligo (January, 1831), affords another example of this phenomenon. After a sudden thaw of snow, the bog between Bloomfield and Geevah gave way; and a black deluge, carrying with it the contents of a hundred acres of bog, took the direction of a small stream, and rolled on with the violence of a torrent, sweeping along heath, timber, mud, and stones, and overwhelming many meadows and arable land. On passing through some boggy land, the flood swept out a wide and deep ravine, and part of the road leading from Bloomfield to St. James's Well was completely carried away from below the foundation for the breadth of 200 yards.

Bones of herbivorous quadrupeds in peat. — The antlers of large and full-grown stags are amongst the most common and conspicuous remains of animals in peat. They are not horns which have been shed; for portions of the skull are found attached, proving that the whole animal perished. Bones of the ox, hog, horse, sheep, and other herbivorous animals, also, occur; and in Ireland and the Isle of Man skeletons of a gigantic elk. M. Morren has discovered in the peat

of Flanders, the bones of otters and beavers *; but no remains have been met with belonging to those extinct quadrupeds of which the living congeners inhabit warmer latitudes, such as the elephant, rhinoceros, hippopotamus, hyæna, and tiger, though these are so common in superficial deposits of silt, mud, sand, or stalactite, in various districts throughout Great Britain. Their absence seems to imply that they had ceased to live before the atmosphere of this part of the world acquired that cold and humid character which favours the growth of peat.

Remains of ships, &c. in peat-mosses. — From the facts before mentioned, that mosses occasionally burst, and descend in a fluid state to lower levels, it will readily be seen that lakes and arms of the sea may occasionally become the receptacles of drift-peat. Of this, accordingly, there are numerous examples; and hence the alternations of clay and sand with different deposits of peat so frequent on some coasts, as on those of the Baltic and German Ocean. We are informed by Deguer that remains of ships, nautical instruments, and oars, have been found in many of the Dutch mosses; and Gerard, in his History of the Valley of the Somme, mentions that in the lowest tier of that moss was found a boat loaded with bricks, proving that these mosses were at one period navigable lakes and arms of the sea, as were also many mosses on the coast of Picardy, Zealand, and Friesland, from which soda and salt are procured.† The canoes, stone hatchets, and stone arrow-heads, found in peat in different parts of Great Britain, lead to similar conclusions.

* Bulletin de la Soc. Géol. de France, tom. ii. p. 26.

† Dr. Rennie, Essays on Peat-Moss, p. 205.

Imbedding of Human and other Remains, and Works of Art, in Blown Sand.

The drifting of sand may next be considered among the causes capable of preserving organic remains and works of art on the emerged land.

African sands. — The sands of the African deserts have been driven by the west winds over parts of the arable land of Egypt, on the western bank of the Nile, in those places where valleys open into the plain, or where there are gorges through the Libyan mountains. By similar sand-drifts the ruins of ancient cities have been buried between the Temple of Jupiter Ammon and Nubia. M. G. A. de Luc attempted to infer the recent origin of our continents, from the fact that these moving sands have arrived only in modern times at the fertile plains of the Nile. The same scourge, he said, would have afflicted Egypt for ages anterior to the times of history, had the continents risen above the level of the sea several hundred centuries before our era.* But the author proceeded in this, as in all his other chronological computations, on a multitude of gratuitous assumptions. He ought, in the first place, to have demonstrated that the whole continent of Africa was raised above the level of the sea at one period; for unless this point was established, the region from whence the sands began to move might have been the last addition made to Africa, and the commencement of the sand flood might have been long posterior to the laying dry of the greater portion of that continent. That the different parts of Europe were not all elevated at one time is now generally

* M. G. A. de Luc, *Mercure de France*, Sept. 1809.

admitted. De Luc should also have pointed out the depth of drift sand in various parts of the great Libyan deserts, and have shown whether any valleys of large dimensions had been filled up — how long these may have arrested the progress of the sands, and how far the flood had upon the whole advanced since the times of history.

We have seen that Sir J. G. Wilkinson is of opinion that, while the sand-drift is making aggressions at certain points upon the fertile soil of Egypt, the alluvial deposit of the Nile is advancing very generally upon the desert; and that, upon the whole, the balance is greatly in favour of the fertilizing mud.*

No mode of interment can be conceived more favourable to the conservation of monuments for indefinite periods than that now so common in the region immediately westward of the Nile. The sand which surrounded and filled the great temple of Ipsambul, first discovered by Burckhardt, and afterwards partially uncovered by Belzoni and Beechey, was so fine as to resemble a fluid when put in motion. Neither the features of the colossal figures, nor the colour of the stucco with which some were covered, nor the paintings on the walls, had received any injury from being enveloped for ages in this dry impalpable dust.†

At some future period, perhaps, when the pyramids shall have perished, the action of the sea, or an earthquake, may lay open to the day some of these buried temples. Or we may suppose the desert to remain undisturbed, and changes in the surrounding sea and land to modify the climate and the direction of the prevailing winds, so that these may then waft away

* See Book II. chap. i.

† Stratton, Ed. Phil. Journ., No. V. p. 62.

the Libyan sands as gradually as they once brought them to those regions. Thus, many a town and temple of higher antiquity than Thebes or Memphis may reappear in their original integrity, and a part of the gloom which overhangs the history of the earlier nations be dispelled.

Whole caravans are said to have been overwhelmed by the Libyan sands ; and Burckhardt informs us that “after passing the Akaba, near the head of the Red Sea, the bones of dead camels are the only guides of the pilgrim through the wastes of sand.” — “ We did not see,” says Captain Lyon, speaking of a plain near the Soudah mountains, in Northern Africa, “ the least appearance of vegetation ; but observed many skeletons of animals, which had died of fatigue on the desert, and occasionally the grave of some human being. All these bodies were so dried by the heat of the sun, that putrefaction appears not to have taken place after death. In recently expired animals I could not perceive the slightest offensive smell ; and in those long dead, the skin with the hair on it remained unbroken and perfect, although so brittle as to break with a slight blow. The sand-winds never cause these carcasses to change their places ; for, in a short time, a slight mound is formed round them, and they become stationary.” *

Towns overwhelmed by sand floods. — The burying of several towns and villages in England, France, and Jutland, by blown sand is on record ; thus, for example, near St. Pol de Leon, in Brittany, a whole village was completely buried beneath drift sand, so that

* Travels in North Africa in the Years 1818, 1819, and 1820, p. 83.

nothing was seen but the spire of the church.* In Jutland marine shells adhering to sea-weed are sometimes blown by the violence of the wind to the height of 100 feet and buried in similar hills of sand.

In Suffolk, in the year 1688, part of Downham was overwhelmed by sands which had broken loose about 100 years before, from a warren five miles to the south-west. This sand had, in the course of a century, travelled five miles, and covered more than 1000 acres of land.† A considerable tract of cultivated land on the north coast of Cornwall has been inundated by drift sand, forming hills several hundred feet above the level of the sea, and composed of comminuted marine shells, in which some terrestrial shells are inclosed entire. By the shifting of these sands the ruins of ancient buildings have been discovered; and in some cases where wells have been bored to a great depth, distinct strata, separated by a vegetable crust, are visible. In some places, as at New Quay, large masses have become sufficiently indurated to be used for architectural purposes. The lapidification, which is still in progress, appears to be due to oxide of iron held in solution by the water which percolates the sand.‡

Imbedding of Organic and other Remains in Volcanic Formations on the Land.

I have in some degree anticipated the subject of this section in a former volume, when speaking of the

* Mém. de l'Acad. des Sci. de Paris, 1772. — See also the case of the buried church of Eccles, above, vol. II. p. 52.

† Phil. Trans., vol. ii. p. 722.

‡ Boase on Submersion of Part of the Mount's Bay, &c., Trans. Roy. Geol. Soc. of Cornwall, vol. ii. p. 140.

buried cities around Naples, and those on the flanks of Etna.* From the facts referred to, it appeared that the preservation of human remains and works of art is frequently due to the descent of floods caused by the copious rains which accompany eruptions. These aqueous lavas, as they are called in Campania, flow with great rapidity; and in 1822 surprised and suffocated, as was stated, seven persons in the villages of St. Sebastian and Massa, on the flanks of Vesuvius.

In the tuffs, moreover, or solidified mud, deposited by these aqueous lavas, impressions of leaves and of trees have been observed. Some of those, formed after the eruption of Vesuvius in 1822, are now preserved in the museum at Naples.

Lava itself may become indirectly the means of preserving terrestrial remains, by overflowing beds of ashes, pumice, and ejected matter, which may have been showered down upon animals and plants, or upon human remains. Few substances are better non-conductors of heat than volcanic dust and scoriæ, so that a bed of such materials is rarely melted by a superimposed lava current. After consolidation, the lava affords secure protection to the lighter and more removable mass below, in which the organic relics may be enveloped. The Herculanean tuffs containing the rolls of Papyrus, of which the characters are still legible, have, as was before remarked, been for ages covered by lava.

Another mode by which lava may tend to the conservation of imbedded remains, at least of works of human art, is by its overflowing them when it is not intensely heated, in which case they sometimes suffer little or no injury.

* Vol. II. pp. 189. 214.

Thus when the Etnean lava-current of 1669 covered fourteen towns and villages, and part of the city of Catania, it did not melt down a great number of statues and other articles in the vaults of Catania; and at the depth of thirty-five feet in the same current, on the site of Mompiliere, one of the buried towns, the bell of a church and some statues were found uninjured.*

There are several buried cities in Central India, which might probably yield a richer harvest to the antiquary than Pompeii and Herculaneum.† The city of Oujein (or Oojain) was, about fifty years before the Christian era, the seat of empire, of art, and of learning; but in the time of the Rajah Vicramaditya, it was overwhelmed, together, as tradition reports, with more than eighty other large towns in the provinces of Malwa and Bagur, "by a shower of earth." The city which now bears the name is situated a mile to the southward of the ancient town. On digging on the spot where the latter is supposed to have stood, to the depth of fifteen or eighteen feet, there are frequently discovered, says Mr. Hunter, entire brick walls, pillars of stone, and pieces of wood of an extraordinary hardness, besides utensils of various kinds, and ancient coins. Many coins are also found in the channels cut by the periodical rains, or in the beds of torrents into which they have been washed. "During our stay at Oujein, a large quantity of wheat was found by a man digging for bricks. It was, as might have been expected, almost entirely consumed, and in a state resembling charcoal. In a ravine cut by the rains, from which several stone pillars had been dug, I saw a space from twelve to fifteen feet long, and seven or eight

* Vol. II. p. 214.

† Vol. II. p. 189.

high, composed of earthen vessels, broken and closely compacted together. It was conjectured, with great appearance of probability, to have been a potter's kiln. Between this place and the new town is a hollow, in which, tradition says, the river Sipparah formerly ran. It changed its course at the time the city was buried, and now runs to the westward." *

The soil which covers Oujein is described as " being of an ash-grey colour, with minute specks of black sand." †

That the "shower of earth" which is reported to have "fallen from heaven" was produced by a volcanic eruption, seems very probable, although no information has been obtained respecting the site of the vent; and the nearest volcano of which we read is that which was in eruption during the Cutch earthquake in 1819, at the distance of about thirty miles from Bhooj, the capital of Cutch, and at least 300 geographical miles from Oujein.

Captain F. Dangerfield, who accompanied Sir John Malcolm in his late expedition into Central India, states that the river Nerbuddah, in Malwa, has its channel excavated through *columnar basalt*, above which are beds of *marl* impregnated with salt. The upper of these marls is of a light colour, and from thirty to forty feet thick, and rests horizontally on the lower bed, which is of a reddish colour. Both appear from the description to be tuffs composed of the materials of volcanic ejections, and forming a covering from sixty to seventy feet deep overlying the basalt, which seems to resemble some of the currents of

* Narrative of Journey from Agra to Oujein, Asiatic Researches, vol. vi. p. 36.

† Asiatic Journal, vol. ix. p. 35.

prismatic lava in Auvergne and the Vivarais. Near the middle of this tufaceous mass, and therefore at the depth of thirty feet or more from the surface, just where the two beds of tuff meet, Captain Dangerfield was shown, near the city of Mhysir, buried bricks and large earthen vessels, said to have belonged to the ancient city of Mhysir, destroyed by the catastrophe of Oujein.*

* Sir J. Malcolm's Cent. Ind. — Geol. of Malwa, by Captain F. Dangerfield, App. No. ii. pp. 324, 325.

CHAPTER XIV.

BURYING OF FOSSILS IN ALLUVIAL DEPOSITS AND IN CAVES..

Fossils in alluvium — Effects of sudden inundations — Terrestrial animals most abundantly preserved in alluvium where earthquakes prevail — Marine alluvium — Buried town — Effects of landslips — Organic remains in fissures and caves — Form and dimensions of caverns — their probable origin — Closed basins and engulfed rivers of the Morea — Katavothra — Formation of breccias with red cement — Human remains imbedded in Morea — Intermixture, in caves of south of France and elsewhere, of human remains and bones of extinct quadrupeds, no proof of former co-existence of man with those lost species.

Alluvium. — THE next subject for our consideration, according to the division before proposed, is the imbedding of organic bodies in alluvium.

The gravel, sand, and mud in the bed of a river does not often contain any animal or vegetable remains ; for the whole mass is so continually shifting its place, and the attrition of the various parts is so great, that even the hardest rocks contained in it are, at length, ground down to powder. But when sand and sediment are suddenly swept by a flood, and then let fall upon the land, such an alluvium may envelop trees or the remains of animals, which, in this manner, are often permanently preserved. In the mud and sand produced by the floods in Scotland, in 1829, the dead and mutilated bodies of hares, rabbits, moles,

mice, partridges, and even the bodies of men, were found partially buried.* But in these and similar cases one flood usually effaces the memorials left by another, and there is rarely a sufficient depth of undisturbed transported matter, in any one spot, to preserve the organic remains for ages from destruction.

Where earthquakes prevail, and the levels of a country are changed from time to time, the remains of animals may more easily be inhumed and protected from disintegration. Portions of plains, loaded with alluvial accumulations by transient floods, may be gradually upraised; and, if any organic remains have been imbedded in the transported materials, they may, after such elevation, be placed beyond the reach of the erosive power of streams. In districts where the drainage is repeatedly deranged by subterranean movements, every fissure, every hollow caused by the sinking in of land, becomes a depository of organic and inorganic substances, hurried along by transient floods.

Marine alluvium. — In May, 1787, a dreadful inundation of the sea was caused at Coringa, Ingeram, and other places, on the coast of Coromandel, in the East Indies, by a hurricane blowing from the N. E., which raised the waters so that they rolled inland to the distance of about twenty miles from the shore, swept away many villages, drowned more than 10,000 people, and left the country covered with marine mud, on which the carcasses of about 100,000 head of cattle were strewed. An old tradition of the natives of a similar flood, said to have happened about a century before, was, till this event, regarded as fabulous by

* Sir T. D. Lauder, Bart., on the great Floods in Morayshire, Aug. 1829, p. 177.

the European settlers.* The same coast of Coromandel was, so late as May, 1832, the scene of another catastrophe of the same kind ; and when the inundation subsided, several vessels were seen grounded in the fields of the low country about Coringa.

Many of the storms termed hurricanes have evidently been connected with submarine earthquakes, as is shown by the atmospheric phenomena attendant on them, and by the sounds heard in the ground, and the odours emitted. Such were the circumstances which accompanied the swell of the sea in Jamaica, in 1780, when a great wave desolated the western coast, and, bursting upon Savanna la Mar, swept away the whole town in an instant, so that not a vestige of man, beast, or habitation, was seen upon the surface.†

Houses and works of art in alluvial deposits. — A very ancient subterranean town, apparently of Hindoo origin, was discovered in India in 1833, in digging the Doab canal. Its site is north of Saharunpore, near the town of Behat, and 17 feet below the present surface of the country. More than 170 coins of silver and copper have already been found, and many articles in metal and earthenware. The overlying deposit consisted of about 5 feet of river sand, with a substratum, about twelve feet thick, of red alluvial clay. In the neighbourhood are several rivers and torrents, which descend from the mountains charged with vast quantities of mud, sand, and shingle ; and within the memory of persons now living the modern Behat has been threatened by an inundation, which after retreating left the neighbouring country strewed over with

* Dodsley's Ann. Regist., 1788.

† Edwards, Hist. of West Indies, vol. i. p. 235. ed. 1801.

a superficial covering of sand several feet thick. In sinking wells in the environs, masses of shingle and boulders have been reached resembling those now in the river-channels of the same district, under a deposit of 30 feet of reddish loam. Captain Cautley, therefore, who directed the excavations, supposes that the matter discharged by torrents has gradually raised the whole country skirting the base of the lower hills ; and that the ancient town, having been originally built in a hollow, was submerged by floods, and covered over with sediment 17 feet in thickness.*

We are informed, by M. Boblaye, that in the Morea, the formation termed *céramique*, consisting of pottery, tiles, and bricks, intermixed with various works of art, enters so largely into the alluvium and vegetable soil upon the plains of Greece, and into hard and crystalline breccias which have been formed at the foot of declivities, that it constitutes an important stratum which might, in the absence of zoological characters, serve to mark our epoch in a most indestructible manner.†

Landslips.—The landslip, by suddenly precipitating large masses of rock and soil into a valley, overwhelms a multitude of animals, and sometimes buries permanently whole villages, with their inhabitants and large herds of cattle. Thus three villages, with their entire population, were covered, when the mountain of Piz fell in 1772, in the district of Treviso, in the state of Venice ‡; and part of Mount Grenier, south of Chambery, in Savoy, which fell down in the year 1248, buried five parishes, including the town and church of

* Journ. of Asiat. Soc., Nos. xxv. and xxix.—1834.

† Ann. des Sci. Nat., tome xxii. p. 117. Feb. 1831.

‡ Malte-Brun's Geog., vol. i. p. 435.

St. André, the ruins occupying an extent of about nine square miles.*

The number of lives lost by the slide of the Rossberg, in Switzerland, in 1806, was estimated at more than 800, a great number of the bodies, as well as several villages and scattered houses, being buried deep under mud and rock. In the same country, several hundred cottages, with eighteen of their inhabitants and a great number of cows, goats, and sheep, were victims to the sudden fall of a bed of stones, thirty yards deep, which descended from the summits of the Diablerets in Vallais. In the year 1618, a portion of Mount Conto fell, in the county of Chiavenna in Switzerland, and buried the town of Pleurs with all its inhabitants, to the number of 2430.

It is unnecessary to multiply examples of similar local catastrophes, which however numerous they may have been in mountainous parts of Europe, within the historical period, have been, nevertheless, of rare occurrence when compared to events of the same kind which have taken place in regions convulsed by earthquakes. It is then that enormous masses of rock and earth, even in comparatively low and level countries, are detached from the sides of valleys, and cast down into the river-courses, and often so unexpectedly that they overwhelm, even in the daytime, every living thing upon the plains.

Preservation of Organic Remains in Fissures and Caves.

In the history of earthquakes it was shown that many hundreds of new fissures and chasms had opened in certain regions during the last 150 years,

* Bakewell, *Travels in the Tarentaise*, vol. i. p. 201.

some of which are described as being of unfathomable depth. We also perceive that mountain masses have been violently fractured and dislocated, during their rise above the level of the sea; and thus we may account for the existence of many cavities in the interior of the earth by the simple agency of earthquakes; but there are some caverns, especially in limestone rocks, which, although usually, if not always, connected with rents, are nevertheless of such forms and dimensions, alternately expanding into spacious chambers, and then contracting again into narrow passages, that it is difficult to conceive that they can owe their origin to the mere fracturing and displacement of solid masses.

In the limestone of Kentucky, in the basin of Green River, one of the tributaries of the Ohio, a line of underground cavities has been traced in one direction for a distance of ten miles, without any termination; and one of the chambers, of which there are many, all connected by narrow tunnels, is no less than ten acres in area, and 150 feet in its greatest height. Besides the principal series of "antres vast," there are a great many lateral embrangements not yet explored.*

The cavernous structure here alluded to is not altogether confined to calcareous rocks; for it has lately been observed in micaceous and argillaceous schist in the Grecian island of Thermia (Cythnos of the ancients), one of the Cyclades. Here also spacious halls, with rounded and irregular walls, are connected together by narrow passages or tunnels, and there are many lateral branches which have no outlet. A current of water has evidently at some period flowed through the whole, and left a muddy deposit of bluish clay upon

* Mem. by Nahum Ward, Trans. of Antiq. Soc. of Massachusetts. Holmes's Un. States, p. 438.

the floor; but the erosive action of the stream cannot be supposed to have given rise to the excavations in the first instance. M. Virlet suggests that fissures were first caused by earthquakes, and that these fissures became the chimneys or vents for the disengagement of gas, generated below by volcanic heat. Gases, he observes, such as the muriatic, sulphuric, fluoric, and others, might, if raised to a high temperature, alter and decompose the rocks which they traverse. There are signs of the former action of such vapours in rents of the micaceous schist of Thermia, and thermal springs now issue from the grottos of that island. We may suppose that afterwards the elements of the decomposed rocks were gradually removed in a state of solution by mineral waters; a theory which, according to M. Virlet, is confirmed by the effect of heated gases which escape from rents in the isthmus of Corinth, and which have greatly altered and corroded the hard siliceous and jaspideous rocks.*

When we reflect on the quantity of carbonate of lime annually poured out by mineral waters, we are prepared to admit that large cavities must, in the course of ages, be formed at considerable depths below the surface in calcareous rocks.† These rocks, it will be remembered, are at once more soluble, more permeable, and more fragile, than any others, at least all the compact varieties are very easily broken by the movements of earthquakes, which would produce only flexures in argillaceous strata. Fissures once formed in limestone are not liable, as in many other formations, to become closed up by impervious clayey matter, and

* Bull. de la Soc. Géol. de France, tom. ii. p. 329.

† See Book II. chap. iv.

hence a stream of acidulous water might for ages obtain a free and unobstructed passage. *

Morea. — Nothing is more common in limestone districts than the engulfment of rivers, which after holding a subterranean course for many miles escape again by some new outlet. As they are usually charged with fine sediment, and often with sand and pebbles where they enter, whereas they are usually pure and limpid where they flow out again, they must deposit much matter in empty spaces in the interior of the earth. In addition to the materials thus introduced, stalagmite, or carbonate of lime, drops from the roofs of caverns, and in this mixture the bones of animals washed in by rivers are often entombed. In this manner we may account for those bony breccias which we often find in caves, some of which are of high antiquity, while others are very recent and in daily progress. In no district are engulfed streams more conspicuous than in the Morea, where the phenomena attending them have been lately studied and described in great detail by M. Boblaye and his fellow-labourers of the French expedition to Greece.† Their account is peculiarly interesting to geologists, because it throws light on the red osseous breccias containing the bones of extinct quadrupeds which are so common in almost all the countries bordering the Mediterranean. It appears that the numerous caverns of the Morea occur in a compact limestone, of the age of the English chalk, immediately below which are arenaceous strata referred to the period of our green sand. In the more elevated districts of that

* See some remarks by M. Boblaye, Ann. des Mines, 3me série, tom. iv.

† See Ann. des Mines, 3me série, tom. iv. 1833.

peninsula there many deep land-locked valleys, or basins, closed round on all sides by mountains of fissured and cavernous limestone. The year is divided almost as distinctly as between the tropics into a rainy season, which lasts upwards of four months, and a season of drought of nearly eight months' duration. When the torrents are swollen by the rains, they rush from surrounding heights into the inclosed basins; but, instead of giving rise to lakes, as would be the case in most other countries, they are received into gulphs or chasms, called by the Greeks "Katavothra," and which correspond to what are termed "swallow-holes" in the north of England. The water of these torrents is charged with pebbles and red ochreous earth, resembling precisely the well-known cement of the osseous breccias of the Mediterranean. It dissolves in acids with effervescence, and leaves a residue of hydrated oxide of iron, granular iron, impalpable grains of silex, and small crystals of quartz. Soil of the same description abounds every where on the surface of the decomposing limestone in Greece, that rock containing in it much siliceous and ferruginous matter.

Many of the Katavothra being insufficient to give passage to all the water in the rainy reason, a temporary lake is formed round the mouth of the chasm, which then becomes still farther obstructed by pebbles, sand, and red mud, thrown down from the turbid waters. The lake being thus raised, its waters generally escape through other openings, at higher levels, around the borders of the plain, constituting the bottom of the closed basin.

In some places, as at Kavaros and Tripolitza, where the principal discharge is by a gulph in the middle of the plain, nothing can be seen over the opening in

summer, when the lake dries up, but a deposit of red mud, cracked in all directions. But the Katavothron is more commonly situated at the foot of the surrounding escarpment of limestone; and in that case there is sometimes room enough to allow a person to enter, in summer, and even to penetrate far into the interior. Within is seen a suite of chambers, communicating with each other by narrow passages; and M. Virlet relates, that in one instance he observed, near the entrance, human bones imbedded in recent red mud, mingled with the remains of plants and animals of species now inhabiting the Morea. It is not wonderful, he says, that the bones of man should be met with in such receptacles; for so murderous have been the late wars in Greece, that skeletons are often seen lying exposed on the surface of the country.*

In summer, when no water is flowing into the Katavothron, its mouth, half closed up with red mud, is masked by a vigorous vegetation, which is cherished by the moisture of the place. It is then the favourite hiding-place and den of foxes and jackals; so that the same cavity serves at one season of the year for the habitation of carnivorous beasts, and at another as the channel of an engulphed river. Near the mouth of one chasm, M. Boblaye and his companions saw the carcass of a horse, in part devoured, the size of which seemed to have prevented the jackals from dragging it in: the marks of their teeth were observed on the bones, and it was evident that the floods of the ensuing winter would wash in whatsoever might remain of the skeleton.

It has been stated that the waters of all these

* Bull. de la Soc. Géol. de France, tom. iii. p. 223.

torrents of the Morea are turbid where they are engulfed ; but when they come out again, often at the distance of many leagues, they are perfectly clear and limpid, being only charged occasionally with a slight quantity of calcareous sand. The points of efflux are usually near the sea-shores of the Morea, but sometimes they are submarine ; and when this is the case, the sands are seen to boil up for a considerable space, and the surface of the sea, in calm weather, swells in large convex waves. It is curious to reflect, that when this discharge fails in seasons of drought, the sea may break into subterraneous caverns, and carry in marine sand and shells, to be mingled with ossiferous mud, and the remains of terrestrial animals.

In general, however, the efflux of water at these inferior openings is surprisingly uniform. It seems, therefore, that the large caverns in the interior must serve as reservoirs, and that the water escapes gradually from them, in consequence of the smallness of the rents and passages by which they communicate with the surface.

The phenomena above described are not confined to the Morea, but occur in Greece generally, and in those parts of Italy, Spain, Asia Minor, and Syria, where the formations of the Morea extend. The Copaic lake in Bœotia has no outlet, except by underground channels ; and hence we can explain those traditional and historical accounts of its having gained on the surrounding plains and overflowed towns, as such floods must have happened whenever the outlet was partially choked up by mud, gravel, or the subsidence of rocks, caused by earthquakes. When speaking of the numerous fissures in the limestone of Greece, M. Boblaye reminds us of the famous earthquake of 469 B.C.,

when, as we learn from Cicero, Plutarch, Strabo, and Pliny, Sparta was laid in ruins, part of the summit of Mount Taygetus torn off, and numerous gulphs and fissures caused in the rocks of Laconia.

During the great earthquake of 1693, in Sicily, several thousand people were at once entombed in the ruins of caverns in limestone, at Sortino Vecchio ; and, at the same time, a large stream, which had issued for ages from one of the grottos below that town, changed suddenly its subterranean course, and came out from the mouth of a cave lower down the valley, where no water had previously flowed. To this new point the ancient water-mills were transferred.*

When the courses of engulfed rivers are thus liable to change, from time to time, by alterations in the levels of a country, and by the rending and shattering of mountain masses, we must suppose that the dens of wild beasts will sometimes be inundated by subterranean floods, and their carcasses buried under heaps of alluvium. The bones, moreover, of individuals which have died in the recesses of caves, or of animals which have been carried in for prey, may be drifted along, and mixed up with mud, sand, and fragments of rocks, so as to form osseous breccias.

In 1833 I had an opportunity of examining the most celebrated caves of Franconia, and among others that of Rabenstein, newly discovered. Their general form, and the nature and arrangement of their contents, appeared to me to agree perfectly with the notion of their having once served as the channels of subterraneous rivers. This mode of accounting for the in-

* I learnt this from some inhabitants of Sortino, in 1829, and visited the points alluded to.

Introduction of transported matter into the Franconian and other caves, filled up as they often are even to their roofs with osseous breccia, was long ago proposed by M. C. Prevost *, and seems at length to be very generally adopted. But I do not doubt that bears inhabited some of the German caves, or that the cavern of Kirkdale, in Yorkshire, was once the den of hyænas. The abundance of bony dung, associated with hyænas' bones, has been pointed out by Dr. Buckland, and with reason, as confirmatory of this opinion.

The same author observed in every cave examined by him in Germany, that deposits of mud and sand, with or without rolled pebbles and angular fragments of rock, were covered over with a *single* crust of stalagmite. † In the English caves he remarked a similar absence of *alternations* of alluvium and stalagmite. But Dr. Schmerling has discovered in a cavern at Chockier, about two leagues from Liège, three distinct beds of stalagmite, and between each of them a mass of breccia, and mud mixed with quartz pebbles, and in the three deposits the bones of extinct quadrupeds. ‡

This exception does not invalidate the generality of the phenomenon pointed out by Dr. Buckland, one cause of which may perhaps be this, that if several floods pass at different intervals of time through a subterranean passage, the last, if it has power to drift along fragments of rock, will also tear up any alternating stalagmitic and alluvial beds that may have been previously formed. Another cause may be, that a particular line of caverns will rarely be so situated, in

* Mém. de la Soc. d'Hist. Nat. de Paris, tom. iv.

† Reliquæ Diluvianæ, p. 108.

‡ Journ. de Géol., tom. i. p. 286, July, 1830.

relation to the lowest levels of a country, as to become, at two distinct epochs, the receptacle of engulfed rivers ; and if this should happen, some of the caves, or at least the tunnels of communication, may at the first period be entirely choked up with transported matter, so as not to allow the subsequent passage of water in the same direction.

As the same chasms may remain open throughout periods of indefinite duration, the species inhabiting a country may in the meantime be greatly changed, and thus the remains of animals belonging to very different epochs may become mingled together in a common tomb. For this reason it is often difficult to separate the monuments of the human epoch from those relating to periods long antecedent, and it was not without great care and skill that Dr. Buckland was enabled to guard against such anachronisms in his investigation of several of the English caves. He mentions that human skeletons were found in the cave of Wokey Hole, near Wells, in the Mendips, dispersed through reddish mud and clay, and some of them united by stalagmite into a firm osseous breccia. "The spot on which they lie is within reach of the highest floods of the adjacent river, and the mud in which they are buried is evidently fluviatile." *

In speaking of the cave of Paviland on the coast of Glamorganshire, the same author states that the entire mass through which bones were dispersed appeared to have been disturbed by ancient diggings, so that the remains of extinct animals had become mixed with recent bones and shells. In the same cave was a human skeleton, and the remains of recent testacea of eatable species, which may have been carried in by man.

* *Reliquiae Diluvianæ*, p. 165.



In several caverns on the banks of the Meuse, near Liège, Dr. Schmerling has found human bones in the same mud and breccia with those of the elephant, rhinoceros, bear, and other quadrupeds of extinct species. He has observed none of the dung of any of these animals; and from this circumstance, and the appearance of the mud and pebbles, he concludes that these caverns were never inhabited by wild beasts, but washed in by a current of water. As the human skulls and bones were in fragments, and no entire skeleton had been found, he does not believe that these caves were places of sepulture, but that the human remains were washed in at the same time as the bones of extinct quadrupeds.

Caverns in the South of France.—Similar associations in the south of France, of human bones and works of art, with remains of extinct quadrupeds, have induced some geologists to maintain that man was an inhabitant of that part of Europe before the rhinoceros, hyæna, tiger, and other fossil species disappeared. I may first mention the cavern of Bize, in the department of Aude, where M. Marcel de Serres met with a small number of human bones mixed with those of extinct animals and with land shells. They occur in a calcareous stony mass, bound together by a cement of stalagmite. On examining the same caverns, M. Tournal found not only in these calcareous beds, but also in a black mud which overlies a red osseous mud, several human teeth, together with broken angular fragments of a rude kind of pottery, and also recent marine and terrestrial shells. The teeth preserve their enamel; but the fangs are so much altered as to adhere strongly when applied to the tongue. Of the terrestrial shells thus associated with the bones

and pottery, the most common are *Cyclostoma elegans*, *Bulinus decollatus*, *Helix nemoralis*, and *H. nitida*. Among the marine are found *Pecten jacobaeus*, *Mytilus edulis*, and *Natica mille-punctata*, all of them eatable kinds, and which may have been brought there for food. Bones were found in the same mass belonging to three new species of deer, an extinct bear (*Ursus arctoideus*), and the wild bull (*Bos urus*), formerly a native of Germany.*

In the same part of France, M. de Christol has found in caverns in a tertiary limestone at Pondres and Souvignargues, two leagues north of Lunel-viel, in the department of Herault, human bones and pottery confusedly mixed with remains of the rhinoceros, bear, hyæna, and other terrestrial mammifers. They were imbedded in alluvial mud, of the solidity of calcareous tufa, and containing some flint pebbles and fragments of the limestone of the country. Beneath this mixed accumulation, which sometimes attained a thickness of thirteen feet, is the original floor of the cavern, about a foot thick, covered with bones and the dung of animals (*album græcum*), in a sandy and tufaceous cement.

The human bones in these caverns of Pondres and Souvignargues were found, upon a careful analysis, to have parted with their animal matter to as great a degree, as those of the hyæna which accompany them, and are equally brittle, and adhere as strongly to the tongue.

In order to compare the degree of alteration of these bones with those known to be of high antiquity, M. Marcel de Serres and M. Ballard, chemists of Montpellier, procured some from a Gaulish sarcopha-

* M. Marcel de Serres, Géognosie des Terrains Tertiaires, p. 64. Introduction.

gus; in the plain of Lunel, supposed to have been buried for fourteen or fifteen centuries at least. In these the cellular tissue was empty, but they were more solid than fresh bones. They did not adhere to the tongue in the same manner as those of the caverns of Bize and Pondres, yet they had lost at least three fourths of their original animal matter.

The superior solidity of the Gaulish bones to those in a fresh skeleton is a fact in perfect accordance with the observations made by Mr. Mantell on bones taken from a Saxon tumulus near Lewes.

M. Teissier has also described a cavern near Mialet, in the department of Gard, where the remains of the bear and other animals were mingled confusedly with human bones, coarse pottery, teeth pierced for amulets, pointed fragments of bone, bracelets of bronze, and a Roman urn. Part of this deposit reached to the roof of the cavity, and adhered firmly to it. The author suggests that the exterior portion of the grotto may at one period have been a den of bears, and that afterwards the aboriginal inhabitants of the country took possession of it either for a dwelling or a burial place, and left there the coarse pottery, amulets, and pointed pieces of bone. At a third period the Romans may have used the cavern as a place of sepulture or concealment, and to them may have belonged the urn and bracelets of metal. If we then suppose the course of the neighbouring river to be impeded by some temporary cause, a flood would be occasioned, which, rushing into the open grotto, may have washed all the remains into the interior caves and tunnels, heaping the whole confusedly together.*

* Bull. de la Soc. Géol. de France, tom. ii. pp. 56—63.

In the controversy which has arisen on this subject MM. Marcel de Serres, De Christol, Tournal, and others, have contended, that the phenomena of this and other caverns in the south of France prove that the fossil rhinoceros, hyæna, bear, and several other lost species, were once contemporaneous inhabitants of the country, together with man; while M. Desnoyers has supported the opposite opinion. The flint hatchets and arrow heads, he says, and the pointed bones and coarse pottery of many French and English caves, agree precisely in character with those found in the tumuli, and under the dolmens (rude altars of unhewn stone) of the primitive inhabitants of Gaul, Britain, and Germany. The human bones, therefore, in the caves which are associated with such fabricated objects, must belong not to antediluvian periods, but to a people in the same stage of civilization as those who constructed the tumuli and altars.

In the Gaulish monuments we find, together with the objects of industry above mentioned, the bones of wild and domestic animals of species now inhabiting Europe, particularly of deer, sheep, wild boars, dogs, horses, and oxen. This fact has been ascertained in Quercy, and other provinces; and it is supposed by antiquaries that the animals in question were placed beneath the Celtic altars in memory of sacrifices offered to the Gaulish divinity Hesus, and in the tombs to commemorate funeral repasts, and also from a superstition prevalent among savage nations, which induces them to lay up provisions for the manes of the dead in a future life. But in none of these ancient monuments have any bones been found of the elephant, rhinoceros, hyæna, tiger, and other quadrupeds, such as are found in caves, as might certainly have been

expected, had these species continued to flourish at the time that this part of Gaul was inhabited by man.*

We are also reminded by M. Desnoyers of a passage in Florus, in which it is related that Cæsar ordered the caves into which the Aquitanian Gauls had retreated to be closed up.† It is also on record, that so late as the eighth century, the Aquitanians defended themselves in caverns against King Pepin. As many of these caverns, therefore, may have served in succession as temples and habitations, as places of sepulture, concealment, or defence, it is easy to conceive that human bones, and those of animals, in osseous breccias of much older date, may have been swept away together, by inundations, and then buried in one promiscuous heap.

It is not on the evidence of such intermixtures that we ought readily to admit either the high antiquity of the human race, or the recent date of certain lost species of quadrupeds.

Among the various modes in which the bones of animals become preserved, independently of the agency of land-floods and engulfed rivers, I may mention that open fissures often serve as natural pitfalls in which herbivorous animals perish. This may happen the more readily when they are chased by beasts of prey, or when surprised while carelessly browsing on the shrubs which so often overgrow and conceal the edges of fissures.‡

During the excavations recently made near Behat in India, the bones of two deer were found at the bottom

* Desnoyers, Bull. de la Soc. Géol. de France, tom. ii. p. 252.

† Hist. Rom. Epit., lib. iii. c. 10.

‡ Buckland, Reliquiæ Diluvianæ, p. 25.

of an ancient well which had been filled up with alluvial loam. Their horns were broken to pieces, but the jaw bones and other parts of the skeleton remained tolerably perfect. "Their presence," says Captain Cautley, "is easily accounted for, as a great number of these and other animals are constantly lost in galloping over the jungles and among the high grass, by falling into deserted wells." *

Above the village of Selside, near Ingleborough in Yorkshire, a chasm of enormous but unknown depth occurs in the scar-limestone, a member of the carboniferous series. "The chasm," says Professor Sedgwick, "is surrounded by grassy shelving banks, and many animals, tempted towards its brink, have fallen down and perished in it. The approach of cattle is now prevented by a strong lofty wall; but there can be no doubt that, during the last two or three thousand years, great masses of bony breccia must have accumulated in the lower parts of the great fissure, which probably descends through the whole thickness of the scar-limestone, to the depth of perhaps five or six hundred feet." †

When any of these natural pit-falls happen to communicate with lines of subterranean caverns, the bones, earth, and breccia, may sink by their own weight, or be washed into the vaults below.

At the north extremity of the rock of Gibraltar are perpendicular fissures, on the ledges of which a number of hawks nestle and rear their young in the breeding season. They throw down from their nests the bones

* See p. 288., and places cited there.

† Memoir on the Structure of the Lake Mountains of the North of England, &c., read before the Geological Society, Jan. 5. 1831.

of small birds, mice, and other animals on which they feed, and these are gradually united into a breccia of angular fragments of the decomposing limestone with a cement of red earth.

At the pass of Escrinet in France, on the northern escarpment of the Coiron hills, near Aubenas, I have seen a breccia in the act of forming. Small pieces of disintegrating limestone are transported, during heavy rains, by a streamlet, to the foot of the declivity, where land shells are very abundant. The shells and pieces of stone soon become cemented together by stalagmite into a compact mass, and the talus thus formed is in one place fifty feet deep, and five hundred yards wide. So firmly is the lowest portion consolidated, that it is quarried for mill-stones.

Recent stalagmitic limestone of Cuba. — One of the most singular examples of the recent growth of stalagmitic limestone in caves and fissures, is that described by Mr. R. C. Taylor, as observable on the north-east part of the island of Cuba.* The country there is composed of a white marble, in which are numerous cavities, partially filled with a calcareous deposit of a brick red colour. In this red deposit are shells, or often the hollow casts of shells, chiefly referable to eight or nine species of land snails, a few scattered bones of quadrupeds, and, what is still more singular, marine univalve shells, often at the height of many hundred, or even one thousand feet above the sea. The following explanation is given of the gradual increase of this deposit. Land shells of the genera *Helix*, *Cyclostoma*, *Pupa*, and *Clausilia*, retire into the caves,

* Notes on Geol. of Cuba, from Observations made in 1836, Phil. Mag., July, 1837.

the floors of which are strewed with myriads of their dead and unoccupied shells, at the same time that water infiltrated through the mountain throws down carbonate of lime, enveloping the shells, together with fragments of the white limestone which occasionally falls from the roof. Multitudes of bats resort to the caves ; and their dung, which is of a bright red colour, (probably derived from the berries on which they feed,) imparts its red hue to the mass. Sometimes also the Hutia, or great Indian rat of the island, dies and leaves its bones in the caves. “ At certain seasons the soldier-crabs resort to the sea-shore, and then return from their pilgrimage, each carrying with them, or rather dragging, the shell of some marine univalve for many a weary mile. They may be traced even at the distance of eight or ten miles from the shore, on the summit of mountains 1200 feet high, like the pilgrims of the olden times, each bearing his shell to denote the character and extent of his wanderings.” By this means several species of marine testacea of the genera *Trochus*, *Turbo*, *Littorina*, and *Monodonta* are conveyed into inland caverns, and enter into the composition of the newly formed rock.

CHAPTER XV.

IMBEDDING OF ORGANIC REMAINS IN SUBAQUEOUS DEPOSITS.

Division of the subject — Imbedding of terrestrial animals and plants — Increased specific gravity of wood sunk to great depths in the sea — Drift timber of the Mackenzie in Slave Lake and Polar Sea — Floating trees in the Mississippi — in the Gulf Stream — on the coast of Iceland, Spitzbergen, and Labrador — Submarine forests — Example on coast of Hampshire — Mineralization of plants — Imbedding of the remains of insects — of reptiles — Bones of birds why rare — Imbedding of terrestrial quadrupeds by river-floods — Skeletons in recent shell marl — Imbedding of mammiferous remains in marine strata.

***Division of the subject.* — HAVING treated of the imbedding of organic remains in deposits formed upon the land, I shall next consider the including of the same in deposits formed under water.**

It will be convenient to divide this branch of our subject into three parts ; considering, first, the various modes whereby the relics of *terrestrial* species may be buried in subaqueous formations ; secondly, the modes whereby animals and plants inhabiting *fresh water* may be so entombed ; thirdly, how *marine* species may become preserved in new strata.

The phenomena above enumerated demand a fuller share of attention than those previously examined, since the deposits which originate upon dry land are insignificant in thickness, superficial extent, and

durability, when contrasted with those of subaqueous origin. At the same time, the study of the latter is beset with greater difficulties; for we are here concerned with the results of processes much farther removed from the sphere of ordinary observation. There is, indeed, no circumstance which so seriously impedes the acquisition of just views in our science as an habitual disregard of the important fact, that the reproductive effects of the principal agents of change are confined to another element — to that larger portion of the globe, from which, by our very organization, we are almost entirely excluded.*

Imbedding of Terrestrial Plants.

When a tree falls into a river from the undermining of the banks, or from being washed in by a torrent or flood, it floats on the surface, not because the woody portion is specifically lighter than water, but because it is full of pores containing air. When soaked for a considerable time, the water makes its way into these pores, and the wood becomes *water-logged* and sinks. The time required for this process varies in different woods; but several kinds may be drifted to great distances, sometimes across the ocean, before they lose their buoyancy.

Wood sunk to a great depth in the sea. — If wood be sunk to vast depths in the sea, it may be impregnated with water suddenly. Captain Scoresby informs us, in his Account of the Arctic Regions, that on one occasion a whale, on being harpooned, ran out all the lines in the boat, which it then dragged under water, to the depth of several thousand feet, the men having

* See Book I. ch. v.

just time to escape to a piece of ice. When the fish returned to the surface "to blow," it was struck a second time, and soon afterwards killed. The moment it expired it began to sink,—an unusual circumstance, which was found to be caused by the weight of the sunken boat, which still remained attached to it. By means of harpoons and ropes the fish was prevented from sinking, until it was released from the weight by connecting a rope to the lines of the attached boat, which was no sooner done than the fish rose again to the surface. The sunken boat was then hauled up with great labour; for so heavy was it, that although before the accident it would have been buoyant when full of water, yet it now required a boat at each end to keep it from sinking. "When it was hoisted into the ship, the paint came off the wood in large sheets; and the planks, which were of wainscot, were as completely soaked in every pore as if they had lain at the bottom of the sea since the flood! A wooden apparatus that accompanied the boat in its progress through the deep, consisting chiefly of a piece of thick deal, about fifteen inches square, happened to fall overboard, and, though it originally consisted of the lightest fir, sank in the water like a stone. The boat was rendered useless: even the wood of which it was built, on being offered to the cook for fuel, was tried and rejected as incombustible."*

Captain Scoresby found that, by sinking pieces of fir, elm, ash, &c., to the depth of four thousand and sometimes six thousand feet, they became impregnated with sea-water, and when drawn up again, after immersion, for an hour, would no longer float. The

* Account of the Arctic Regions, vol. ii. p. 193.

effect of this impregnation was to increase the dimensions as well as the specific gravity of the wood, every solid inch having increased one-twentieth in size and twenty-one twenty-fifths in weight.*

Drift-wood of the Mackenzie River. — When timber is drifted down by a river, it is often arrested by lakes : and, becoming water-logged, it may sink and be imbedded in lacustrine strata, if any be there forming : sometimes a portion floats on till it reaches the sea. In the course of the Mackenzie River we have an example of vast accumulations of vegetable matter now in progress under both these circumstances.

In Slave Lake in particular, which vies in dimensions with some of the great fresh-water seas of Canada, the quantity of drift-timber brought down annually is enormous. "As the trees," says Dr. Richardson, "retain their roots, which are often loaded with earth and stones, they readily sink, especially when water-soaked ; and, accumulating in the eddies, form shoals, which ultimately augment into islands. A thicket of small willows covers the new-formed island as soon as it appears above water, and their fibrous roots serve to bind the whole firmly together. Sections of these islands are annually made by the river, assisted by the frost ; and it is interesting to study the diversity of appearances they present, according to their different ages. The trunks of the trees gradually decay until they are converted into a blackish brown substance resembling peat, but which still retains more or less of the fibrous structure of the wood ; and layers of this often alternate with layers of clay and sand, the whole being penetrated, to the depth of four or

* Account of the Arctic Regions, vol. ii. p. 202.

five yards or more, by the long fibrous roots of the willows. A deposition of this kind, with the aid of a little infiltration of bituminous matter, would produce an excellent imitation of coal, with vegetable impressions of the willow-roots. What appeared most remarkable was the horizontal slaty structure that the old alluvial banks presented, or the *regular curve* that the strata assumed from unequal subsidence.

"It was in the rivers only that we could observe sections of these deposits; but the same operation goes on on a much more magnificent scale in the lakes. A shoal of many miles in extent is formed on the south side of Athabasca Lake, by the drift-timber and vegetable debris brought down by the Elk River; and the Slave Lake itself must in process of time be filled up by the matters daily conveyed into it from Slave River. Vast quantities of drift-timber are buried under the sand at the mouth of the river, and enormous piles of it are accumulated on the shores of every part of the lake." *

The banks of the Mackenzie display almost everywhere horizontal beds of wood coal, alternating with bituminous clay, gravel, sand, and friable sandstone; sections, in short, of such deposits as are now evidently forming at the bottom of the lakes which it traverses.

Notwithstanding the vast forests intercepted by the lakes, a still greater mass of drift-wood is found where the Mackenzie reaches the sea, in a latitude where no wood grows at present except a few stunted willows. At the mouths of the river the alluvial matter has formed a barrier of islands and shoals, where we

* Dr. Richardson's Geognost. Obs. on Capt. Franklin's Polar Expedition.

may expect a great formation of coal at some distant period.

The abundance of floating timber on the Mackenzie is owing, as Dr. Richardson informs me, to the direction and to the length of the course of this river, which runs from south to north, so that the sources of the stream lie in much warmer latitudes than its mouths. In the country, therefore, where the sources are situated, the frost breaks up at an earlier season, while yet the waters in the lower part of its course are ice-bound. Hence the current of water, rushing down northward, reaches a point where the thaw has not begun, and, finding the channel of the river blocked up with ice, it overflows the banks, sweeping through forests of pines, and carrying away thousands of uprooted trees.

Drift-wood of the Mississippi. — I have already observed that the navigation of the Mississippi is much impeded by trunks of trees half sunk in the river.* On reaching the Gulf of Mexico many of them subside, and are imbedded in the new strata which form the delta, but many of them float on and enter the Gulf stream. “ Tropical plants (says M. Constant Prevost) are taken up by this great current, and carried in a northerly direction till they reach the shores of Iceland and Spitzbergen uninjured. A great portion of them are doubtless arrested on their passage, and probably always in the same inlets, or the same spots on the bottom of the ocean ; in fact, wherever an eddy or calm determines their distribution, which, in this single example, extends over a space comprehended between the equator and the eightieth degree

* Book II. chap. ii.

of latitude — an immense space, six times more considerable than that occupied by all Europe, and thirty times larger than France. The drifting of various substances, though regular, is not continual: it takes place by intermittence after great inundations of rivers, and in the intervals the waters may carry sand only or mud, or each of these alternately, to the same localities." *

Drift-timber on coasts of Iceland, Spitzbergen, &c.— The ancient forests of Iceland, observes Malte-Brun, have been improvidently exhausted; but, although the Icelander can obtain no timber from the land, he is supplied with it abundantly by the ocean. An immense quantity of thick trunks of pines, firs, and other trees, are thrown upon the northern coast of the island, especially upon North Cape and Cape Langanness, and are then carried by the waves along these two promontories to other parts of the coast, so as to afford sufficiency of wood for fuel and for constructing boats. Timber is also carried to the shores of Labrador and Greenland; and Crantz assures us that the masses of floating wood thrown by the waves upon the island of John de Mayen often equal the whole of that island in extent. †

In a similar manner the bays of Spitzbergen are filled with drift-wood, which accumulates also upon those parts of the coast of Siberia that are exposed to the east, consisting of larch trees, pines, Siberian cedars, firs, and Fernambucco and Campeachy woods. These trunks appear to have been swept away by the

* Mém. de la Soc. d'Hist. Nat. de Paris, vol. iv. p. 84.

† Malte-Brun, Geog., vol. v. part i. p. 112. — Crantz, Hist. of Greenland, tome i. pp. 50—54.

great rivers of Asia and America. Some of them are brought from the Gulf of Mexico, by the Bahama stream; while others are hurried forward by the current which, to the north of Siberia, constantly sets in from east to west. Some of these trees have been deprived of their bark by friction, but are in such a state of preservation as to form excellent building timber.* Parts of the branches and almost all the roots remain fixed to the pines which have been drifted into the North Sea, into latitudes too cold for the growth of such timber, but the trunks are usually barked.

The leaves and lighter parts of plants are seldom carried out to sea, in any part of the globe, except during tropical hurricanes among islands, and during the agitations of the atmosphere which sometimes accompany earthquakes and volcanic eruptions.†

Comparative number of living and fossilized species of plants.—It will appear from these observations that, although the remains of terrestrial vegetation, borne down by aqueous causes from the land, are chiefly deposited at the bottom of lakes or at the mouths of rivers; yet a considerable quantity is drifted about in all directions by currents, and may become imbedded in any *marine* formation, or may sink down, when water-logged, to the bottom of unfathomable abysses, and there accumulate without intermixture of other substances.

It may be asked whether we have any data for inferring that the remains of a considerable proportion of the existing species of plants will be permanently pre-

* Olafsen, *Voyage to Iceland*, tome i. Malte-Brun's Geog. vol. v. part i. p. 112.

† De la Beche, *Geol. Manual*, p. 477.

served, so as to be hereafter recognizable, supposing the strata now in progress to be at some future period upraised? To this inquiry it may be answered, that there are no reasons for expecting that more than a small number of the plants now flourishing in the globe will become fossilized; since the entire habitations of a great number of them are remote from lakes and seas, and even where they grow near to large bodies of water, the circumstances are quite accidental and partial which favour the imbedding and conservation of vegetable remains. Suppose, for example, that the species of plants inhabiting the hydrographical basin of the Rhine, or that region, extending from the Alps to the sea, which is watered by the Rhine and its numerous tributaries, to be about 2500 in number, exclusive of the cryptogamic class. This estimate is by no means exaggerated; yet if a geologist could explore the deposits which have resulted from the sediment of the Rhine in the lake of Constance, and off the coast of Holland, he might scarcely be able to obtain from the recent strata the leaves, wood, and seeds of *fifty* species in such a state of preservation as to enable a botanist to determine their specific characters with certainty.

Those naturalists, therefore, who infer that the ancient flora of the globe was, at certain periods, less varied than now, merely because they have as yet discovered only a few hundred fossil species of a particular epoch, while they can enumerate more than fifty thousand living ones, are reasoning on a false basis, and their standard of comparison is not the same in the two cases.

Submarine forest on coast of Hants.—We have already seen that the submarine position of several

forests, or the remains of trees standing in a vertical position on the British shores has been due, in some instances, to the subsidence of land.* There are some cases which require a different explanation. The Honourable Charles Harris discovered, in 1831, evident traces of a fir-wood, beneath the mean level of the sea, at Bournemouth, in Hampshire, the formation having been laid open during a low spring tide. It is composed of peat and wood, and is situated between the beach and a bar of sand about 200 yards off, and extends fifty yards along the shore. It also lies in the direct line of the Bournemouth Valley, from the termination of which it is separated by 200 yards of shingle and drift-sand. Down the valley flows a large brook, traversing near its mouth a considerable tract of rough, boggy, and heathy ground, which produces a few birch trees, and a great abundance of the *Myrica Gale*. Seventy-six rings of annual growth were counted in a transverse section of one of the buried fir trees, which was fourteen inches in diameter. Besides the stumps and roots of fir, pieces of alder and birch are found in the peat; and it is a curious fact, that a part of many of the trees has been converted into iron pyrites. The peat rests on pebbly strata, precisely similar to the sand and pebbles occurring on the adjoining heaths.

As the sea is encroaching on this shore, we may suppose that at some former period the Bourne Valley extended farther, and that its extremity consisted, as at present, of boggy ground, partly clothed with fir-trees. The bog rested on that bed of pebbles which we now see below the peat; and the sea, in its progressive encroachments, eventually laid bare, at low

* See Vol. II. pp. 46. and 80.

water, the sandy foundations; upon which a stream of fresh water rushing through the sand at the fall of the tides, carried out loose sand with it. The superstratum of vegetable matter being matted and bound together by the roots of trees, remained; but being undermined, sank down below the level of the sea, and then the waves washed sand and shingle over it. In support of this hypothesis, it may be observed, that small streams of fresh water often pass under the sands of the sea-beach, so that they may be crossed dry-shod; and the water is seen, at the point where it issues, to carry out sand and even pebbles.

Mineralization of plants.—Although the botanist and chemist have as yet been unable to explain fully the manner in which wood becomes petrified, it is nevertheless ascertained that, under favourable circumstances, the lapidifying process is now continually going on. A piece of wood was lately procured by Mr. Stokes, from an ancient Roman aqueduct in Westphalia, in which some portions were converted into spindle-shaped bodies, consisting of carbonate of lime, while the rest of the wood remained in a comparatively unchanged state.* It appears that in some cases the most perishable, in others the most durable, portions of plants are preserved, variations which doubtless depend on the time when the mineral matter was supplied. If introduced immediately, on the first commencement of decomposition, then the most destructible parts are lapidified, while the more durable do not waste away till afterwards, when the supply has failed, and so never become petrified. The converse of these circumstances gives rise to exactly opposite results.

* Geol. Trans., second series, vol. v. p. 212.

Professor Göppert, of Breslau, has instituted a series of curious experiments, in which he has succeeded in producing some very remarkable imitations of fossil petrifactions. He placed recent ferns between soft layers of clay, dried these in the shade, and then slowly and gradually heated them, till they were red hot. The result was the production of so perfect a counterpart of fossil plants as might have deceived an experienced geologist. According to the different degrees of heat applied, the plants were obtained in a brown or perfectly carbonized condition; and sometimes, but more rarely, they were in a black shining state, adhering closely to the layer of clay. If the red heat was sustained until all the organic matter was burnt up, only an impression of the plant remained.

The same chemist steeped plants in a moderately strong solution of sulphate of iron, and left them immersed in it for several days, until they were thoroughly soaked in the liquid. They were then dried, and kept heated until they would no longer shrink in volume, and until every trace of organic matter had disappeared. On cooling them he found that the oxide formed by this process had taken the form of the plants. A variety of other experiments were made by steeping animal and vegetable substances in siliceous, calcareous, and metallic solutions, and all tended to prove that the mineralization of organic bodies can be carried much farther in a short time than had been previously supposed.*

* Göppert, Poggendorff's Annalen der Physik und Chemie, vol. xxxviii. part iv., Leipsic. 1836.

Imbedding of the Remains of Insects.

I have observed the elytra and other parts of beetles in a band of fissile clay, separating two beds of recent shell-marl, in the Loch of Kinnordy in Forfarshire. Amongst these, Mr. Curtis recognized *Elater lineatus* and *Atopa cervina*, species still living in Scotland. These, as well as other remains which accompanied them, appear to belong to terrestrial, not aquatic, species, and must have been carried down in muddy water during an inundation. In the lacustrine peat of the same locality, the elytra of beetles are not uncommon ; but in the deposits of drained lakes generally, and in the silt of our estuaries, the relics of this class of the animal kingdom are rare. In the blue clay of very modern origin of Lewes levels, Mr. Mantell has found the Indusia, or cases of the larvæ of Phryganea, in abundance, with minute shells belonging to the genera *Planorbis*, *Limnea*, &c., adhering to them.*

When speaking of the migrations of insects, I pointed out that an immense number are floated into lakes and seas by rivers, or blown by winds far from the land ; but they are so buoyant that we can only suppose them, under very peculiar circumstances, to sink to the bottom before they are either devoured by insectivorous animals or decomposed.

Remains of Reptiles.

As the bodies of several crocodiles were found in the mud brought down to the sea by the river inundation which attended an earthquake in Java, in the year 1699, we may imagine that extraordinary floods of

* Trans. Geol. Soc., vol. iii. part i. p. 201. second series.

mud may stifle many individuals of the shoals of alligators and other reptiles which frequent lakes and the deltas of rivers in tropical climates. Thousands of frogs were found leaping about among the wreck, carried into the sea by the inundations in Morayshire, in 1829*; and it is evident that whenever a sea-cliff is undermined, or land is swept by other violent causes into the sea, land reptiles may be carried in.

Remains of Birds.

We might have anticipated that the imbedding of the remains of birds in new strata would be of very rare occurrence, for their powers of flight insure them against perishing by numerous casualties to which quadrupeds are exposed during floods; and if they chance to be drowned, or to die when swimming on the water, it will scarcely ever happen that they will be submerged so as to become preserved in sedimentary deposits. In consequence of the hollow tubular structure of their bones and the quantity of their feathers, they are extremely light in proportion to their volume; so that when first killed they do not sink to the bottom like quadrupeds, but float on the surface until the carcass either rots away or is devoured by predaceous animals. To these causes we may ascribe the absence of any vestige of the bones of birds in the recent marl formations of Scotland; although these lakes, until the moment when they were artificially drained, were frequented by a great abundance of water-fowl.

* Sir T. D. Lauder's Account, second edition, p. 312.

Imbedding of Terrestrial Quadrupeds.

River inundations recur in most climates at very irregular intervals, and expend their fury on those rich alluvial plains, where herds of herbivorous quadrupeds congregate together. These animals are often surprised ; and, being unable to stem the current, are hurried along until they are drowned, when they sink at first immediately to the bottom. Here their bodies are drifted along, together with sediment, into lakes or seas, and may then be covered by a mass of mud, sand, and pebbles, thrown down upon them. If there be no sediment superimposed, the gases generated by putrefaction usually cause the bodies to rise again to the surface about the ninth, or at latest the fourteenth day. The pressure of a thin covering of mud would not be sufficient to retain them at the bottom ; for we see the putrid carcasses of dogs and cats, even in rivers, floating with considerable weights attached to them, and in sea-water they would be still more buoyant.

Where the body is so buried in drift-sand, or mud accumulated upon it, as never to rise again, the skeleton may be preserved entire ; but if it comes again to the surface while in the process of putrefaction, the bones commonly fall piecemeal from the floating carcass, and may in that case be scattered at random over the bottom of the lake, estuary, or sea ; so that a jaw may afterwards be found, in one place, a rib in another, a humerus in a third — all included, perhaps, in a matrix of fine materials, where there may be evidence of very slight transporting power in the current, or even of none, but simply of some chemical precipitate.

A large number of the bodies of drowned animals, if they float into the sea or a lake, especially in hot climates, are instantly devoured by sharks, alligators, and other carnivorous beasts, which may have power to digest even the bones; but during extraordinary floods, when the greatest number of land animals are destroyed, the waters are commonly so turbid, especially at the bottom of the channel, that even aquatic species are compelled to escape into some retreat where there is clearer water, lest they should be stifled. For this reason, as well as the rapidity of sedimentary deposition at such seasons, the probability of carcasses becoming permanently imbedded is considerable.

Flood in the Solway Firth, 1794. — One of the most memorable floods of modern date, in our island, is that which visited part of the southern borders of Scotland, on the 24th of January, 1794, and which spread particular devastation over the country adjoining the Solway Firth.

We learn from the account of Captain Napier, that the heavy rains had swollen every stream which entered the Firth of Solway; so that the inundation not only carried away a great number of cattle and sheep, but many of the herdsmen and shepherds, washing down their bodies into the estuary. After the storm, when the flood subsided, an extraordinary spectacle was seen on a large sand-bank, called “the beds of Esk,” where there is a meeting of the tidal waters, and where heavy bodies are usually left stranded after great floods. On this single bank were found collected together the bodies of 9 black cattle, 3 horses, 1840 sheep, 45 dogs, 180 hares, besides a great number of

smaller animals, and, mingled with the rest, the corpses of two men and one woman.*

Floods in Scotland, 1829. — In those more recent floods in Scotland, in August, 1829, whereby a fertile district on the east coast became a scene of dreadful desolation, a vast number of animals and plants were washed from the land, and found scattered about after the storm, around the mouths of the principal rivers. An eye-witness thus describes the scene which presented itself at the mouth of the Spey, in Morayshire : — “ For several miles along the beach crowds were employed in endeavouring to save the wood and other wreck with which the heavy-rolling tide was loaded ; whilst the margin of the sea was strewed with the carcasses of domestic animals, and with millions of dead hares and rabbits.” †

Savannahs of South America. — We are informed by Humboldt, that during the periodical swellings of the large rivers in South America great numbers of quadrupeds are annually drowned. Of the wild horses, for example, which graze in immense troops in the savannahs, thousands are said to perish when the river Apure, a tributary of the Orinoco, is swollen, before they have time to reach the rising ground of the Llanos. The mares, during the season of high water, may be seen, followed by their colts, swimming about and feeding on the grass, of which the top alone waves above the waters. In this state they are pursued by crocodiles ; and their thighs frequently bear the prints of the teeth of these carnivorous reptiles. “ Such is the pliability,” observes the celebrated traveller, “ of

* *Treatise on Practical Store Farming*, p. 25.

† *Sir T. D. Lauder’s Floods in Morayshire, 1829*, p. 312., second ed. ; and see above, Book II. chap. i.

the organization of the animals which man has subjected to his sway, that horses, cows, and other species of European origin, lead, for a time, an amphibious life, surrounded by crocodiles, water-serpents, and manatees. When the rivers return again into their beds, they roam in the savannah, which is then spread over with a fine odoriferous grass, and enjoy, as in their native climate, the renewed vegetation of spring." *

Floods of the Parana. — The great number of animals which are drowned in seasons of drought in the tributaries of the Plata, was before mentioned. Sir W. Parish states, that the Parana flowing from the mountains of Brazil to the estuary of the Plata, is liable to great floods, and during one of these, in the year 1812, vast quantities of cattle were carried away, " and when the waters began to subside, and the islands which they had covered became again visible, the whole atmosphere for a time was poisoned by the effluvia from the innumerable carcasses of skunks, capiguaras, tigers, and other wild beasts which had been drowned." †

Floods of the Ganges. — We find it continually stated, by those who describe the Ganges and Burrampooter, that these rivers carry before them, during the flood season, not only floats of reeds and timber, but dead bodies of men, deer, and oxen. ‡

In Java, 1699. — I have already referred to the effects of a flood which attended an earthquake in Java in 1699, when the turbid waters of the Batavian river destroyed all the fish except the carp; and when

* Humboldt's Pers. Nar., vol. iv. pp. 394—396.

† Buenos Ayres and La Plata, p. 187.

‡ Malte-Brun, Geog., vol. iii. p. 22.

drowned buffaloes, tigers, rhinoceroses, deer, apes, and other wild beasts, were brought down to the sea-coast by the current, with several crocodiles which had been stifled in the mud.*

On the western side of the same island, in the territory of Galongoon, in the Regencies, a more recent volcanic eruption (that of 1822, before described †) was attended by a flood, during which the river Tandoi bore down hundreds of carcasses of rhinoceroses and buffaloes, and swept away more than one hundred men and women from a multitude assembled on its banks to celebrate a festival. Whether the bodies reached the sea, or were deposited, with drift matter, in some of the large intervening alluvial plains, we are not informed. ‡

Sumatra. — “On the coast of Orissa,” says Héynes, “I have seen tigers and whole herds of black cattle carried along by what are called freshes, and trees of immense size.” §

In Virginia, 1771. — I might enumerate a great number of local deluges that have swept through the fertile lands bordering on large rivers, especially in tropical countries, but I should surpass the limits assigned to this work. I may observe, however, that the destruction of the islands, in rivers, is often attended with great loss of lives. Thus when the principal river in Virginia rose, in 1771, to the height of twenty-five feet above its ordinary level, it swept entirely away Elk Island, on which were seven hundred head of

* See Vol. II. p. 376.

† Vol. II. p. 263.

‡ This account I had from Mr. Baumhauer, Director-General of Finances in Java.

§ Tracts on India, p. 397

quadrupeds, — horses, oxen, sheep, and hogs, — and nearly one hundred houses.*

The reader will gather, from what was before said respecting the deposition of sediment by aqueous causes, that the greater number of the remains of quadrupeds drifted away by rivers must be intercepted by lakes before they reach the sea, or buried in fresh-water formations near the mouths of rivers. If they are carried still farther, the probabilities are increased of their rising to the surface in a state of putrefaction, and, in that case, of being there devoured by aquatic beasts of prey, or of subsiding into some spots whither no sediment is conveyed, and, consequently, where every vestige of them will, in the course of time, disappear.

Skeletons of animals in recent shell-marl, Scotland.— In some instances, the skeletons of quadrupeds are met with abundantly in recent shell-marls in Scotland, where we cannot suppose them to have been imbedded by the action of rivers or floods. They all belong to species which now inhabit, or are known to have been indigenous in Scotland. The remains of several hundred skeletons have been procured within the last century, from five or six small lakes in Forfarshire, where shell-marl has been worked. Those of the stag (*Cervus elaphus*) are most numerous; and if the others be arranged in the order of their relative abundance, they will follow nearly thus — the ox, the boar, the horse, the sheep, the dog, the hare, the fox, the wolf, and the cat. The beaver seems extremely rare; but it has been found in the shell-marl of Loch Marlie, in Perthshire, and in the parish of Edrom, in Berwickshire.

* Scots Mag., vol. xxxiii.

In the greater part of these lake-deposits there are no signs of floods; and the expanse of water was originally so confined, that the smallest of the above-mentioned quadrupeds could have crossed, by swimming, from one shore to the other. Deer, and such species as take readily to the water, may often have been mired in trying to land, where the bottom was soft and quaggy, and in their efforts to escape may have plunged deeper into the marly bottom. Some individuals, I suspect, of different species, have fallen in when crossing the frozen surface in winter; for nothing can be more treacherous than the ice when covered with snow, in consequence of the springs, which are numerous, and which, retaining always an equal temperature, cause the ice, in certain spots, to be extremely thin, while in every other part of the lake it is strong enough to bear the heaviest weights.

Mammiferous remains in marine strata. — As the bones of mammalia are often so abundantly preserved in peat, and such lakes as have just been described, the encroachments of a sea upon a coast may sometimes throw down the imbedded skeletons, so that they may be carried away by tides and currents, and entombed in subaqueous formations. Some of the smaller quadrupeds, also, which burrow in the ground, as well as reptiles and every species of plant, are liable to be cast down into the waves by this cause, which must not be overlooked, although probably of comparatively small importance amongst the numerous agents whereby terrestrial organic remains are included in submarine strata.

During the great earthquake of Conception in 1835, some cattle, which were standing on the steep sides of

the island of Quiriquina, were rolled by the shock into the sea, while on a low island at the head of the Bay of Conception seventy animals were washed off by a great wave and drowned.*

* Darwin's Journal, p. 372.

CHAPTER XVI.

IMBEDDING OF THE REMAINS OF MAN AND HIS WORKS IN SUBAQUEOUS STRATA.

Drifting of human bodies to the sea by river inundations — Destruction of bridges and houses — Loss of lives by shipwreck — How human corpses may be preserved in recent deposits — Number of wrecked vessels — Fossil skeletons of men — Fossil canoes, ships, and works of art — Chemical changes which metallic articles have undergone after long submergence — Imbedding of cities and forests in subaqueous strata by subsidence — Earthquake of Cutch in 1819 — Berkley's arguments for the recent date of the creation of man — Concluding remarks.

I SHALL now proceed to inquire in what manner the mortal remains of man and the works of his hands may be permanently preserved in subaqueous strata. Of the many hundred million human beings which perish in the course of every century on the land, every vestige is usually destroyed in the course of a few thousand years; but of the smaller number that perish in the waters, a considerable proportion must frequently be entombed under such circumstances, that parts of them may endure throughout entire geological epochs.

The bodies of men, together with those of the inferior animals, are occasionally washed down during river inundations into seas and lakes.* Belzoni wit-

* See pp. 323. 325.

nessed a flood on the Nile in September, 1818, where, although the river rose only three feet and a half above its ordinary level, several villages, with some hundreds of men, women, and children, were swept away.* It was before mentioned that a rise of six feet of water in the Ganges, in 1763, was attended with a much greater loss of lives.†

In the year 1771, when the inundations in the north of England appear to have equalled the recent floods in Morayshire, a great number of houses and their inhabitants were swept away by the rivers Tyne, Can, Wear, Tees, and Greta; and no less than twenty-one bridges were destroyed in the courses of these rivers. At the village of Bywell the flood tore the dead bodies and coffins out of the churchyard, and bore them away, together with many of the living inhabitants. During the same tempest an immense number of cattle, horses, and sheep, were also transported to the sea, while the whole coast was covered with the wreck of ships. Four centuries before (in 1338), the same district had been visited by a similar continuance of heavy rains followed by disastrous floods, and it is not improbable that these catastrophes may recur periodically, though after uncertain intervals. As the population increases, and buildings and bridges are multiplied, we must expect the loss of lives and property to augment.‡

Fossilization of human bodies in the bed of the sea. — If to the hundreds of human bodies committed to the deep in the way of ordinary burial we add those of individuals lost by shipwrecks, we shall find that, in

* *Narrative of Discovery in Egypt, &c., London, 1820.*

† Vol. II. p. 7.

‡ *Scots Mag., vol. xxxiii., 1771.*

the course of a single year, a great number of human remains are consigned to the subaqueous regions. I shall hereafter advert to a calculation by which it appears that more than five hundred *British* vessels alone, averaging each a burthen of about 120 tons, are wrecked, and sink to the bottom, *annually*. Of these the crews for the most part escape, although it sometimes happens that all perish. In one great naval action several thousand individuals sometimes share a watery grave.

Many of these corpses are instantly devoured by predaceous fish, sometimes before they reach the bottom; still more frequently when they rise again to the surface, and float in a state of putrefaction. Many decompose on the floor of the ocean, where no sediment is thrown down upon them; but if they fall upon a reef where corals and shells are becoming agglutinated into a solid rock, or subside where the delta of a river is advancing, they may be preserved for an incalculable series of ages.

Often at the distance of a few hundred feet from a coral reef, where wrecks are not unfrequent, there are no soundings at the depth of many hundred fathoms. Canoes, merchant vessels, and ships of war may have sunk and have been enveloped, in such situations, in calcareous sand and breccia, detached by the breakers from the summit of a submarine mountain. Should a volcanic eruption happen to cover such remains with ashes and sand, and a current of lava be afterwards poured over them, the ships and human skeletons might remain uninjured beneath the superincumbent mass, like the houses and works of art in the subterranean cities of Campania. Already many human remains may have been thus preserved beneath form-

ations more than a thousand feet in thickness ; for, in some volcanic archipelagos, a period of thirty or forty centuries might well be supposed sufficient for such an accumulation.

It was stated, that at the distance of about forty miles from the base of the delta of the Ganges, there is a circular space about fifteen miles in diameter where soundings of from 600 to 800 feet sometimes fail to reach the bottom.* As during the flood season the quantity of mud and sand poured by the great rivers into the Bay of Bengal is so great that the sea only recovers its transparency at the distance of sixty miles from the coast, this depression must be gradually shoaling, especially as during the monsoons, the sea loaded with mud and sand, is beaten back in that direction towards the delta. Now, if a ship or human body sink down to the bottom in such a spot, it is by no means improbable that it may become buried under a depth of a thousand feet of sediment in the same number of years.

Even on that part of the floor of the ocean to which no accession of drift matter is carried (a part which probably constitutes, at any given period, by far the larger proportion of the whole submarine area), there are circumstances accompanying a wreck which favour the conservation of skeletons. For when the vessel fills suddenly with water, especially in the night, many persons are drowned between decks and in their cabins, so that their bodies are prevented from rising again to the surface. The vessel often strikes upon an uneven bottom, and is overturned ; in which case the ballast, consisting of sand, shingle, and rock, or the cargo,

* Vol. II. p. 3.

frequently composed of heavy and durable materials, may be thrown down upon the carcasses. In the case of ships of war, cannon, shot, and other warlike stores, may press down with their weight the timbers of the vessel as they decay, and beneath these and the metallic substances the bones of man may be preserved.

Number of wrecked vessels. — When we reflect on the number of curious monuments consigned to the bed of the ocean in the course of every naval war from the earliest times, our conceptions are greatly raised respecting the multiplicity of lasting memorials which man is leaving of his labours. During our last great struggle with France, thirty-two of our ships of the line went to the bottom in the space of twenty-two years, besides seven 50-gun ships, eighty-six frigates, and a multitude of smaller vessels. The navies of the other European powers, France, Holland, Spain, and Denmark, were almost annihilated during the same period, so that the aggregate of their losses must have many times exceeded that of Great Britain. In every one of these ships were batteries of cannon constructed of iron or brass, whereof a great number had the dates and places of their manufacture inscribed upon them in letters cast in metal. In each there were coins of copper, silver, and often many of gold, capable of serving as valuable historical monuments; in each were an infinite variety of instruments of the arts of war and peace; many formed of materials, such as glass and earthenware, capable of lasting for indefinite ages when once removed from the mechanical action of the waves, and buried under a mass of matter which may exclude the corroding action of sea-water. The quantity moreover of timber which is conveyed from the land to the bed of the sea by the sinking of ships

of a large size is enormous, for it is computed that 2000 tons of wood are required for the building of one 74-gun ship; and reckoning fifty oaks of 100 years growth to the acre, it would require forty acres of oak forest to build one of these vessels.*

It would be an error to imagine that the fury of war is more conducive than the peaceful spirit of commercial enterprise to the accumulation of wrecked vessels in the bed of the sea. From an examination of Lloyd's lists, from the year 1793 to the commencement of 1829, Capt. W. H. Smyth ascertained that the number of *British vessels* alone lost during that period amounted on an average to no less than one and a half *daily*; an extent of loss which would hardly have been anticipated, although we learn from Moreau's tables that the number of merchant vessels employed at one time, in the navigation of England and Scotland, amounts to about twenty thousand, having one with another a mean burthen of 120 tons.† My friend, Mr. J. L. Prevost also informs me that on inspecting Lloyd's lists for the years 1829, 1830, and 1831, he finds that no less than 1953 vessels were lost in those three years, their average tonnage being about 150 tons, or in all nearly 300,000 tons, being at the enormous rate of 100,000 tons annually of the merchant vessels of one nation only. This increased loss arises, I presume, from increasing activity in commerce.

Out of 551 ships of the royal navy lost to the country during the period above mentioned, only 160 were taken or destroyed by the enemy, the rest having either stranded or foundered, or having been burnt by accident; a striking proof that the dangers of our

* Quart. Journ. of Agricult. No. ix. p. 433.

† Cœsar Moreau's Tables of the Navigation of Great Britain.

naval warfare, however great, may be far exceeded by the storm, the shoal, the lee-shore, and all the other perils of the deep.*

Durable nature of many of their contents. — Millions of silver dollars and other coins have been sometimes submerged in a single ship, and on these, when they happen to be enveloped in a matrix capable of protecting them from chemical changes, much information of historical interest will remain inscribed, and endure for periods as indefinite as have the delicate markings of zoophytes or lapidified plants in some of the ancient secondary rocks. In almost every large ship, moreover, there are some precious stones set in seals, and other articles of use and ornament composed of the hardest substances in nature, on which letters and various images are carved — engravings which they may retain when included in subaqueous strata, as long as a crystal preserves its natural form.

It was, therefore, a splendid boast, that the deeds of the English chivalry at Agincourt made Henry's chronicle

————— as rich with praise
As is the ooze and bottom of the deep
With sunken wreck and sumless treasures;

for it is probable that a greater number of monuments of the skill and industry of man will, in the course of ages, be collected together in the bed of the ocean, than will exist at any one time on the surface of the continents.

If our species be of as recent a date as is generally supposed, it will be vain to seek for the remains of man

* I give these results on the authority of Captain W. H. Smyth, R. N.

and the works of his hands imbedded in submarine strata, except in those regions where violent earthquakes are frequent, and the alterations of relative level so great, that the bed of the sea may have been converted into land within the historical era. We need not despair, however, of the discovery of such monuments, when those regions which have been peopled by man from the earliest ages, and which are at the same time the principal theatres of volcanic action, shall be examined by the joint skill of the antiquary and geologist.

Power of human remains to resist decay. — There can be no doubt that human remains are as capable of resisting decay as are the harder parts of the inferior animals; and I have already cited the remark of Cuvier, that “in ancient fields of battle the bones of men have suffered as little decomposition as those of horses which were buried in the same grave.”* In the delta of the Ganges bones of men have been found in digging a well at the depth of ninety feet†; but as that river frequently shifts its course and fills up its ancient channels, we are not called upon to suppose that these bodies are of extremely high antiquity, or that they were buried when that part of the surrounding delta where they occur was first gained from the sea.

Fossil skeletons of men. — Several skeletons of men, more or less mutilated, have been found in the West Indies, on the north-west coast of the main land of Guadaloupe, in a kind of rock which is known to be forming daily, and which consists of minute fragments of shells and corals, incrusted with a calcareous cement

* Vol. I. p. 250.

† Von Hoff, vol. i. p. 379.

resembling travertin, by which also the different grains are bound together. The lens shows that some of the fragments of coral composing this stone still retain the same red colour which is seen in the reefs of living coral which surround the island. The shells belong to species of the neighbouring sea intermixed with some terrestrial kinds which now live on the island, and among them is the *Bulimus Guadaloupensis* of Féruccac. The human skeletons still retain some of their animal matter, and all their phosphate of lime. One of them, of which the head is wanting, may now be seen in the British Museum, and another in the Royal Cabinet at Paris. According to Mr. König, the rock in which the former is inclosed is harder under the mason's saw and chisel than statuary marble. It is described as forming a kind of glacis, probably an indurated beach, which slants from the steep cliffs of the island to the sea, and is nearly all submerged at high tide.

Similar formations are in progress in the whole of the West Indian archipelago, and they have greatly extended the plain of Cayes in St. Domingo, where fragments of vases and other human works have been found at a depth of twenty feet. In digging wells also near Catania, in Sicily, tools have been discovered in a rock somewhat similar.

Buried ships, canoes, and works of art. — When a vessel is stranded in shallow water, it usually becomes the nucleus of a sand-bank, as has been exemplified in several of our harbours, and this circumstance tends greatly to its preservation. Between the years 1780 and 1790 a vessel from Purbeck, laden with three hundred tons of stone, struck on a shoal off the entrance of Poole harbour and foundered; the crew were

saved, but the vessel and cargo remain to this day at the bottom. Since that period the shoal at the entrance of the harbour has so extended itself in a westerly direction towards Peveril Point in Purbeck, that the navigable channel is thrown a mile nearer that point.* The cause is obvious ; the tidal current deposits the sediment with which it is charged around any object which checks its velocity. Matter also drifted along the bottom is arrested by any obstacle, and accumulates round it, just as the African sand-winds, before described, raise a small hillock over the carcass of every dead camel exposed on the surface of the desert.

I before alluded to an ancient Dutch vessel, discovered in the deserted channel of the river Rother, in Sussex, of which the oak wood was much blackened, but its texture unchanged.† The interior was filled with fluviatile silt, as was also the case in regard to a vessel discovered in a former bed of the Mersey, and another disinterred where the St. Katherine Docks are excavated in the alluvial plain of the Thames. In like manner many ships have been found preserved entire in modern strata, formed by the silting up of estuaries along the southern shores of the Baltic, especially in Pomerania. Between Bromberg and Nakel, for example, a vessel and two anchors in a very perfect state were dug up far from the sea.‡

Several vessels have been lately detected half buried in the delta of the Indus, in the numerous deserted branches of that river, far from where the stream now flows. One of these, found near Vikkar

* This account I received from the Honourable Chas. Harris.

† Vol. II. p. 70.

‡ Von Hoff, vol. i. p. 368.

in Sind, was 400 tons in burthen, old fashioned, and pierced for fourteen guns, and in a region where it had been matter of dispute whether the Indus had ever been navigable by large vessels.*

At the mouth of a river in Nova Scotia, a schooner of thirty-two tons, laden with live stock, was lying with her side to the tide, when the bore, or tidal wave, which rises there about ten feet in perpendicular height, rushed into the estuary and overturned the vessel, so that it instantly disappeared. After the tide had ebbed, the schooner was so totally buried in the sand, that the taffrel or upper rail over the stern was alone visible.† We are informed by Leigh that, on draining Martin Meer, a lake eighteen miles in circumference, in Lancashire, a bed of marl was laid dry, wherein no fewer than eight canoes were found imbedded. In figure and dimensions they were not unlike those now used in America. In a morass about nine miles distant from this Meer a whetstone and an axe of mixed metal were dug up.‡ In Ayrshire, also, three canoes were found in Loch Doon some few years ago; and during the year 1831 four others, each hewn out of separate oak trees. They were twenty-three feet in length, two and a half in depth, and nearly four feet in breadth at the stern. In the mud which filled one of them was found a war-club of oak and a stone battle-axe. A canoe of oak was also found in 1820, in peat overlying the shell-marl of the Loch of Kinnordy in Forfarshire. §

Manner in which ships may be preserved in a deep

* Lieut. Carless, Geograph Journ vol. viii. p. 338.

† Silliman's Geol. Lectures, p. 78., who cites Penn.

‡ Leigh's Lancashire, p. 17., A.D. 1700.

§ Geol. Trans., second series, vol. ii. p. 87.

sea.—It is extremely possible that the submerged woodwork of ships which have sunk where the sea is two or three miles deep has undergone greater chemical changes in an equal space of time, than in the cases above mentioned; for the experiments of Scoresby show that wood may at certain depths be impregnated in a single hour with salt-water, so that its specific gravity is entirely altered. It may often happen that hot springs charged with carbonate of lime, silex, and other mineral ingredients, may issue at great depths, in which case every pore of the vegetable tissue may be injected with the lapidifying liquid, whether calcareous or siliceous, before the smallest decay commences. The conversion, also, of wood into lignite is probably more rapid under enormous pressure. But the change of the timber into lignite or coal would not prevent the original form of a ship from being distinguished; for as we find, in strata of the carboniferous era, the bark of the hollow reed-like trees converted into coal, and the central cavity filled with sandstone, so might we trace the outline of a ship in coal; while in the indurated mud, sandstone, or limestone, filling the interior, we might discover instruments of human art, ballast consisting of rocks foreign to the rest of the stratum, and other contents of the ship.

Submerged metallic substances.—Many of the metallic substances which fall into the waters probably lose, in the course of ages, the forms artificially imparted to them; but under certain circumstances these may be preserved for indefinite periods. The cannon inclosed in a calcareous rock, drawn up from the delta of the Rhone, which is now in the museum at Montpellier, might probably have endured as long

as the calcareous matrix; but even if the metallic matter had been removed, and had entered into new combinations, still a mould of its original shape would have been left, corresponding to those impressions of shells which we see in rocks, from which all the carbonate of lime has been subtracted. About the year 1776, says Mr. King, some fishermen, sweeping for anchors in the Gull stream (a part of the sea near the Downs), drew up a very curious old swivel gun, near eight feet in length. The barrel, which was about five feet long, was of brass; but the handle by which it was traversed was about three feet in length, and the swivel and pivot on which it turned were of iron. Around these latter were formed incrustations of sand converted into a kind of stone, of an exceedingly strong texture and firmness; whereas round the barrel of the gun, except where it was near adjoining to the iron, there was no such incrustation, the greater part of it being clean, and in good condition, just as if it had still continued in use. In the incrusting stone, adhering to it on the outside, were a number of shells and corallines, "just as they are often found in a fossil state." These were all so strongly attached, that it required as much force to separate them from the matrix "as to break a fragment off any hard rock." *

In the year 1745, continues the same writer, the Fox man-of-war was stranded on the coast of East Lothian, and went to pieces. About thirty-three years afterwards a violent storm laid bare a part of the wreck, and threw up near the place several masses, "consisting of iron, ropes, and balls," covered over with ochreous sand, concreted and hardened into a

kind of stone. The substance of the rope was very little altered. The consolidated sand retained perfect impressions of parts of an iron ring, "just as impressions of extraneous fossil bodies are found in various kinds of strata." *

After a storm in the year 1824, which occasioned a considerable shifting of the sands near St. Andrew's, in Scotland, a gun-barrel of ancient construction was found, which is conjectured to have belonged to one of the wrecked vessels of the Spanish Armada. It is now in the museum of the Antiquarian Society of Scotland, and is incrusted over by a thin coating of sand, the grains of which are cemented by brown ferruginous matter. Attached to this coating are fragments of various shells, as of the common cardium, mya, &c.

Many other examples are recorded of iron instruments taken up from the bed of the sea near the British coasts, incased by a thick coating of conglomerate, consisting of pebbles and sand, cemented by oxide of iron.

Dr. Davy describes a bronze helmet, of the antique Grecian form, taken up in 1825, from a shallow part of the sea, between the citadel of Corfu and the village of Castrades. Both the interior and exterior of the helmet were partially incrusted with shells, and a deposit of carbonate of lime. The surface generally, both under the incrustation, and where freed from it, was of a variegated colour, mottled with spots of green, dirty white, and red. On minute inspection with a lens, the green and red patches proved to consist of crystals of the red oxide and carbonate of copper, and the dirty white chiefly of oxide of tin.

* Phil. Trans. vol. lxix., 1779.

The mineralizing process, says Dr. Davy, which has produced these new combinations, has, in general, penetrated very little into the substance of the helmet. The incrustation and rust removed, the metal is found bright beneath; in some places considerably corroded, in others very slightly. It proves, on analysis, to be copper, alloyed with 18·5 per cent. of tin. Its colour is that of our common brass, and it possesses a considerable degree of flexibility.

"It is a curious question," he adds, "how the crystals were formed in the helmet, and on the adhering calcareous deposit. There being no reason to suppose deposition from solution, are we not under the necessity of inferring, that the mineralizing process depends on a small motion and separation of the particles of the original compound? This motion may have been due to the operation of electro-chemical powers which may have separated the different metals of the alloy."*

Effects of the Subsidence of Land, in imbedding Cities and Forests in subaqueous Strata.

We have hitherto considered the transportation of plants and animals from the land by aqueous agents, and their inhumation in lacustrine or submarine deposits, and we may now inquire what tendency the subsidence of tracts of land may have to produce analogous effects. Several examples of the sinking down of buildings, and portions of towns near the shore, to various depths beneath the level of the sea during subterranean movements, were before enumerated in treating of the changes brought about by *inorganic* causes. The events alluded to were comprised within

* Phil. Trans. 1826, part ii. p. 55.

a brief portion of the historical period, and confined to a small number of the regions of active volcanos. Yet these authentic facts, relating merely to the last century and a half, gave indications of considerable changes in the physical geography of the globe, and we are not to suppose that these were the only spots throughout the surrounding land and sea, which suffered similar depressions.

If, during the short period since South America has been colonized by Europeans, we have proof of alterations of level at the three principal ports on the western shores, Callao, Valparaiso, and Conception*, we cannot for a moment suspect that these cities, so distant from each other, have been selected as the peculiar points where the desolating power of the earthquake has expended its chief fury. "It would be a knowing arrow that could choose out the brave men from the cowards," retorted the young Spartan, when asked if his comrades who had fallen on the field of battle were braver than he and his fellow-prisoners; we might, in the same manner, remark that a geologist must attribute no small discrimination and malignity to the subterranean force, if he should suppose it to spare habitually a line of coast many thousand miles in length, with the exception of those few spots where populous towns have been erected. On considering how small is the area occupied by the seaports of this disturbed region,—points where alone each slight change of the relative level of the sea and land can be recognized, and reflecting on the proofs in our possession, of the local revolutions that have happened on the site of each port, within the last century and a half

* See Vol. II. pp. 297. 302. 370. 374.

— our conceptions must be greatly exalted respecting the magnitude of the alterations which the country between the Andes and the sea may have undergone, even in the course of the last six thousand years.

Cutch earthquake. — The manner in which a large extent of surface may be submerged, so that the terrestrial plants and animals may be imbedded in subaqueous strata, cannot be better illustrated than by the earthquake of Cutch, in 1819, before alluded to.* It is stated, that, for some years after that earthquake, the withered tamarisks and other shrubs protruded their tops above the waves, in parts of the lagoon formed by subsidence, on the site of the village of Sindree and its environs; but, after the flood of 1826, they were seen no longer. Every geologist will at once perceive, that forests sunk by such subterranean movements may become imbedded in subaqueous deposits, both fluviatile and marine, and the trees may still remain erect, or sometimes the roots and part of the trunks may continue in their original position, while the current may have broken off, or levelled with the ground, their upper stems and branches.

Buildings how preserved under water. — Some of the buildings which have at different times subsided beneath the level of the sea have been immediately covered up to a certain extent with strata of volcanic matter showered down upon them. Such was the case at Tomboro in Sumbawa, in the present century, and at the site of the Temple of Serapis, in the environs of Puzzuoli, probably in the 12th century. The entrance of a river charged with sediment in the vicinity may still more frequently occasion the rapid envelopment

* Vol. II. p. 306.

of buildings in regularly stratified formations. But if no foreign matter be introduced, the buildings, when once removed to a depth where the action of the waves is insensible, and where no great current happens to flow, may last for indefinite periods, and be as durable as the floor of the ocean itself, which may often be composed of the very same materials. There is no reason to doubt the tradition mentioned by the classic writers, that the submerged Grecian towns of Bura and Helice were seen under water; and it has been already mentioned that different eye-witnesses have observed the houses of Port Royal, at the bottom of the sea, at intervals of 88, 101, and 143 years after the convulsion of 1692.*

Berkeley's arguments for the recent date of the creation of man.—I cannot conclude this chapter without recalling to the reader's mind a memorable passage written by Bishop Berkeley a century ago, in which he inferred, on grounds which may be termed strictly geological, the recent date of the creation of man. “To any one,” says he, “who considers that on digging into the earth, such quantities of shells, and in some places bones and horns of animals, are found sound and entire, after having lain there in all probability some thousands of years; it should seem probable that guns, medals, and implements in metal or stone might have lasted entire, buried under ground forty or fifty thousand years, if the world had been so old. How comes it then to pass that no remains are found, no antiquities of those numerous ages preceding the Scripture accounts of time; that no fragments of buildings, no public monuments, no intaglios, cameos, statues, basso-

* Vol. II. p. 380.

relievos, medals, inscriptions, utensils, or artificial works of any kind, are ever discovered, which may bear testimony to the existence of those mighty empires, those successions of monarchs, heroes, and demi-gods, for so many thousand years? Let us look forward and suppose ten or twenty thousand years to come, during which time we will suppose that plagues, famine, wars, and *earthquakes* shall have made great havoc in the world, is it not highly probable that at the end of such a period, pillars, vases, and statues now in being of granite, or porphyry, or jasper, (stones of such hardness as we know them to have lasted two thousand years above ground, without any considerable alteration,) would bear record of these and past ages? Or that some of our current coins might then be dug up, or old walls and the foundations of buildings show themselves, as well as the shells and stones of *the primeval world*, which are preserved down to our times." *

That many signs of the agency of man would have lasted at least as long as "the shells of the primeval world," had our race been so ancient, we may feel as fully persuaded as Berkeley; and we may anticipate with confidence that many edifices and implements of human workmanship and the skeletons of men, and casts of the human form, will continue to exist when a great part of the present mountains, continents, and seas, have disappeared. Assuming the future duration of the planet to be indefinitely protracted, we can foresee no limit to the perpetuation of some of the memorials of man, which are continually entombed in

* *Alciphron, or the Minute Philosopher*, vol. ii. pp. 84, 85.
1732.

the bowels of the earth or in the bed of the ocean, unless we carry forward our views to a period sufficient to allow the various causes of change, both igneous and aqueous, to remodel more than once the entire crust of the earth. *One* complete revolution will be inadequate to efface every monument of our existence; for many works of art might enter again and again into the formations of successive eras, and escape obliteration even though the very rocks in which they had been for ages imbedded were destroyed, just as pebbles included in the conglomerates of one epoch often contain the organized remains of beings which flourished during a prior era.

Yet it is no less true, as a late distinguished philosopher has declared, "that none of the works of a mortal being can be eternal."* They are in the first place wrested from the hands of man, and lost as far as regards their subserviency to his use, by the instrumentality of those very causes which place them in situations where they are enabled to endure for indefinite periods. And even when they have been included in rocky strata, when they have been made to enter as it were into the solid framework of the globe itself, they must nevertheless eventually perish; for every year some portion of the earth's crust is shattered by earthquakes or melted by volcanic fire, or ground to dust by the moving waters on the surface. "The river of Lethe," as Bacon eloquently remarks, "runneth as well above ground as below."†

* Davy, Consolations in Travel, p. 276.

† Essay on the Vicissitude of Things.

CHAPTER XVII.

IMBEDDING OF AQUATIC SPECIES IN SUBAQUEOUS STRATA.

Inhumation of fresh-water plants and animals — Shell marl — Fossilized seed-vessels and stems of chara — Recent deposits in American lakes — Fresh-water species drifted into seas and estuaries — Lewes levels — Alternations of marine and fresh-water strata, how caused — Imbedding of marine plants and animals — Cetacea stranded on our shores — Liability of littoral and estuary testacea to be swept into the deep sea — Effects of a storm in the Frith of Forth — Burrowing shells secured from the ordinary action of waves and currents — Living testacea found at considerable depths — Extent of some recent shelly deposits.

HAVING treated of the imbedding of terrestrial plants and animals, and of human remains, in deposits now forming beneath the waters, I come next to consider in what manner *aquatic* species may be entombed in strata formed in their own element.

Fresh-water plants and animals. — The remains of species belonging to those genera of the animal and vegetable kingdoms which are more or less exclusively confined to fresh water are for the most part preserved in the beds of lakes or estuaries, but they are often-times swept down by rivers into the sea, and there intermingled with the exuviae of marine races. The phenomena attending their inhumation in lacustrine deposits are sometimes revealed to our observation by

the drainage of small lakes, such as are those in Scotland, which have been laid dry for the sake of obtaining shell marl for agricultural uses.

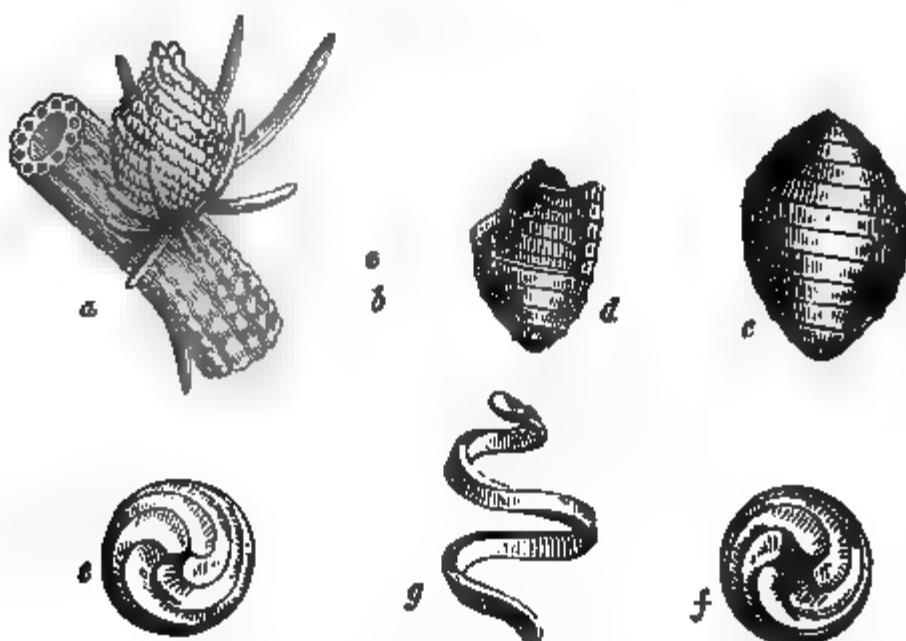
In these recent formations, as seen in Forfarshire, two or three beds of calcareous marl are sometimes observed separated from each other by layers of drift peat, sand, or fissile clay. The marl often consists almost entirely of an aggregate of shells of the genera *limnea*, *planorbis*, *valvata*, and *cyclas*, of species now existing in Scotland. A considerable proportion of the testacea appear to have died very young, and few of the shells are of a size which indicates their having attained a state of maturity. The shells are sometimes entirely decomposed, forming a pulverulent marl; sometimes in a state of good preservation. They are frequently intermixed with stems of *charæ* and other aquatic vegetables, the whole being matted together and compressed, forming laminæ often as thin as paper.

Fossilized seed-vessels and stems of chara. — As the *chara* is an aquatic plant, which occurs frequently fossil in formations of different eras, and is often of much importance to the geologist in characterizing entire groups of strata, I shall describe the manner in which I have found the recent species in a petrified state. They occur in a marl-lake in Forfarshire, inclosed in nodules, and sometimes in a continuous stratum of a kind of travertin.

The seed-vessel of these plants is remarkably tough and hard, and consists of a membranous nut covered by an integument (*d*, fig. 78.), both of which are spirally striated or ribbed. The integument is composed of five spiral valves, of a quadrangular form (*g*). In *Chara hispida*, which abounds in the lakes of Forfar-

shire, and which has become fossil in the Bakie Loch, each of the spiral valves of the seed-vessel turns rather more than twice round the circumference, the whole together making between ten and eleven rings. The number of these rings differs greatly in different species, but in the same appears to be very constant.

Fig. 78.

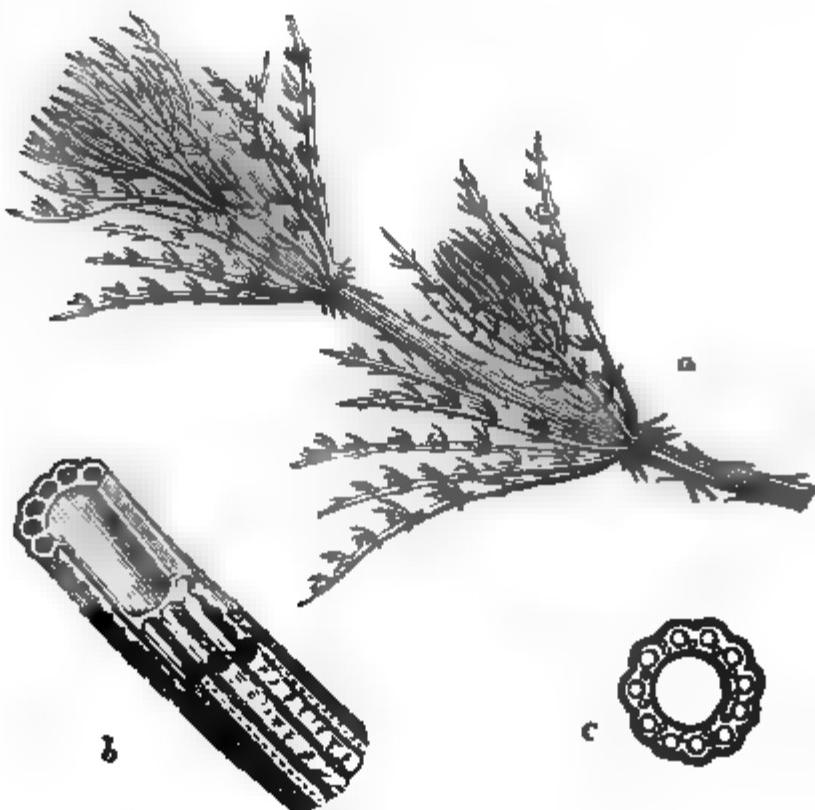
Seed-vessel of *Chara hispida*.

- a, Part of the stem with the seed-vessel attached. Magnified.
- b, Natural size of the seed-vessel.
- c, Integument of the Gyrogonite, or petrified seed-vessel of *Chara hispida*, found in the Scotch marl-lakes. Magnified.
- d, Section showing the nut within the integument.
- e, Lower end of the integument to which the stem was attached.
- f, Upper end of the integument to which the stigmata were attached.
- g, One of the spiral valves of c.

The stems of charæ occur fossil in the Scotch marl in great abundance. In some species, as in *Chara hispida*, the plant when living contains so much carbonate of lime in its vegetable organization, independently of calcareous incrustation, that it effervesces strongly with acids when dry. The stems of *Chara*

Aispirida are longitudinally striated, with a tendency to be spiral. These striae, as appears to be the case with all charæ, turn always like the worm of a screw from right to left, while those of the seed-vessel wind round in a contrary direction. A cross section of the stem exhibits a curious structure, for it is composed of a large tube surrounded by smaller tubes (fig. 79., b, c), as is seen in some extinct as well as recent species.

Fig. 79.

Stem and branches of *Chera Aispirida*.

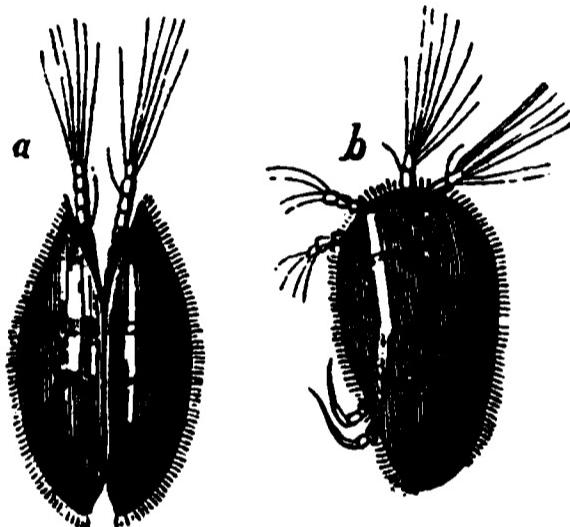
- a, Stem and branches of the natural size.
- b, Section of the stem magnified.
- c, Showing the central tube surrounded by two rings of smaller tubes.

In the stems of several species, however, there is only a single tube.*

* On Fresh-water Marl, &c. By C. Lyell. Geol. Trans., vol. ii., second series, p. 79.

The valves of a small animal called cypris (*C. ornata?* Lam.) occur completely fossilized, like the stems of charæ, in the Scotch travertin above mentioned. The same cypris inhabits the lakes and ponds of England, where, together with many other species, it is not uncommon. Although extremely minute, they are visible to the naked eye, and may be observed in great numbers, swimming swiftly through the waters of our stagnant pools and ditches. The antennæ, at the end of which

Fig. 80.



Cypris unifasciata, a living species, greatly magnified.

a, Upper part. *b*, Side view of the same.

are fine pencils of hair, are the principal organs for swimming, and are moved with great rapidity. The animal resides within two small valves, not unlike those of a bivalve shell, and moults its integuments annually, which the conchiferous molluscs do not. The cast-off shells resembling thin scales, and occurring in countless myriads in many ancient fresh-water marls, impart to them a divisional structure, like that so frequently derived from plates of mica.

Recent deposits in North American lakes. — The recent strata of lacustrine origin above alluded to are

Fig. 81.



Cypris vidua, a living species greatly magnified.*

* See Desmarest's Crustacea, pl. 55.

of very small extent, but analogous deposits on the grandest scale are forming in the great lakes of North America. By the subsidence of the waters of Lakes Superior and Huron, occasioned probably by the partial destruction of their barriers at some unknown period, beds of sand 150 feet thick are exposed, below which are seen beds of clay, inclosing shells of the very species which now inhabit the lake.*

But no careful examination appears as yet to have been made of recent fresh-water formations within the tropics, where the waters teem with life, and where in the bed of a newly-drained lake the remains of the alligator, crocodile, tortoise, and perhaps some large fish, might be discovered.

Imbedding of fresh-water Species in Estuary and Marine Deposits.

In Lewes levels.—We have sometimes an opportunity of examining the deposits which within the historical period have silted up some of our estuaries; and excavations made for wells and other purposes, where the sea has been finally excluded, enable us to observe the state of the organic remains in these tracts. The valley of the Ouse between Newhaven and Lewes is one of several estuaries from which the sea has retired within the last seven or eight centuries; and here, as appears from the researches of Mr. Mantell, strata thirty feet and upwards in thickness have accumulated. At the top, beneath the vegetable soil, is a bed of peat about five feet thick, inclosing many trunks of trees. Next below is a

* Dr. Bigsby, *Journal of Science, &c.* No. xxxvii. pp. 262, 263.

stratum of blue clay containing fresh-water shells of about nine species, such as now inhabit the district. Intermixed with these was observed the skeleton of a deer. Lower down, the layers of blue clay contain, with the above-mentioned fresh-water shells, several marine species well known on our coast. In the lowest beds, often at the depth of thirty-six feet, these marine testacea occur without the slightest inter-mixture of fluviatile species, and amongst them the skull of the narwal, or sea unicorn (*Monodon monoceros*), has been detected. Underneath all these deposits is a bed of pipe-clay, derived from the subjacent chalk.*

If we had no historical information respecting the former existence of an inlet of the sea in this valley and of its gradual obliteration, the inspection of the section above described would show, as clearly as a written chronicle, the following sequence of events. First, there was a salt-water estuary peopled for many years by species of marine testacea identical with those now living, and into which some of the larger cetacea occasionally entered. Secondly, the inlet grew shallower, and the water became brackish, or alternately salt and fresh, so that the remains of fresh-water and marine shells were mingled in the blue argillaceous sediment of its bottom. Thirdly, the shoaling continued until the river-water prevailed, so that it was no longer habitable by marine testacea, but fitted only for the abode of fluviatile species and aquatic insects. Fourthly, a peaty swamp or morass was formed, where some trees grew, or perhaps were

* Mantell, Geol. of Sussex, p. 285. ; also Catalogue of Org. Rem., Geol. Trans., vol. iii. part i. p. 201., second series.

drifted during floods, and where terrestrial quadrupeds were mired. Finally, the soil being flooded by the river only at distant intervals, became a verdant meadow.

In delta of Ganges. — It was before stated, that on the sea-coast, in the delta of the Ganges, there are eight great openings, each of which has evidently, at some ancient periods, served in its turn as the principal channel of discharge.* Now, as the base of the delta is 200 miles in length, it must happen that, as often as the great volume of river-water is thrown into the sea by a new mouth, the sea will at one point be converted from salt to fresh, and at another from fresh to salt; for, with the exception of those parts where the principal discharge takes place, the salt-water not only washes the base of the delta, but enters far into every creek and lagoon. It is evident, then, that repeated alternations of beds containing fresh-water shells, with others filled with corals and marine exuviae, may here be formed; and each series may be of great thickness, as the sea on which the Gangetic delta gains is of considerable depth, and intervals of centuries elapse between each alteration in the course of the principal stream.

In delta of Indus. — Analogous phenomena must sometimes be occasioned by such alternate elevation and depression of the land as was shown to be taking place in the delta of the Indus.† But the subterranean movements affect but a small number of the deltas formed at one period on the globe; whereas, the silting up of some of the arms of great rivers and the opening of others, and the consequent variation of

* Vol. II. p. 3.

† Vol. II. p. 307.

the points where the chief volume of their waters is discharged into the sea, are phenomena common to almost every delta.

The variety of species of testacea contained in the recent calcareous marl of Scotland, before mentioned, is very small, but the abundance of individuals extremely great, a circumstance very characteristic of fresh-water formations in general, as compared to marine ; for in the latter, as is seen on sea-beaches, coral reefs, or in the bottom of seas examined by dredging, wherever the individual shells are exceedingly numerous, there rarely fails to be a vast variety of species.

Imbedding of the Remains of Marine Plants and Animals.

Marine Plants.—The large banks of drift sea-weed which occur on each side of the equator in the Atlantic, Pacific, and Indian oceans, were before alluded to.* These, when they subside, may often produce considerable beds of vegetable matter. In Holland, submarine peat is derived from fuci, and on parts of our own coast from *Zostera marina*. In places where algæ do not generate peat, they may nevertheless leave traces of their form imprinted on argillaceous and calcareous mud, as they are usually very tough in their texture.

Cetacea.—It is not uncommon for the larger cetacea, which can float only in a considerable depth of water, to be carried during storms or high tides into estuaries, or upon low shores, where, upon the retiring of high water, they are stranded. Thus a narwal (*Monodon*

* Page 99.

monoceros) was found on the beach near Boston in Lincolnshire, in the year 1800, the whole of its body buried in the mud. A fisherman going to his boat saw the horn and tried to pull it out, when the animal began to stir itself.* An individual of the common whale (*Balaena mysticetus*), which measured seventy feet, came ashore near Peterhead, in 1682. Many individuals of the genus *Balaenoptera* have met the same fate. It will be sufficient to refer to those cast on shore near Burnt Island, and at Alloa, recorded by Sibbald and Neill. The other individual mentioned by Sibbald, as having come ashore at Boyne, in Banffshire, was probably a razor-back. Of the genus *Catodon* (*Cachalot*), Ray mentions a large one stranded on the west coast of Holland in 1598, and the fact is also commemorated in a Dutch engraving of the time of much merit. Sibbald, too, records that a herd of Cachalots, upwards of 100 in number, were found stranded at Kairston, in Orkney. The dead bodies of the larger cetacea are sometimes found floating on the surface of the waters, as was the case with the immense whale exhibited in London in 1831. And the carcass of a sea-cow or Lamantine (*Halicora*) was, in 1785, cast ashore near Leith.

To some accident of this kind, we may refer the position of the skeleton of a whale, seventy-three feet long, which was found at Airthrey, on the Forth, near Stirling, imbedded in clay twenty feet higher than the surface of the highest tide of the river Forth at the present day. From the situation of the Roman station and causeways at a small distance from the spot, it is

* Fleming's Brit. Animals, p. 37. ; in which work may be seen many other cases enumerated.

concluded that the whale must have been stranded there at a period prior to the Christian era.*

Other fossil remains of this class have also been found in estuaries, known to have been silted up in recent times, one example of which has been already mentioned near Lewes, in Sussex.

Marine reptiles. — Some singular fossils have lately been discovered in the island of Ascension, in a stone said to be continually forming on the beach, where the waves throw up small rounded fragments of shells and corals, which, in the course of time, become firmly agglutinated together, and constitute a stone used largely for building and making lime. In a quarry on the N. W. side of the island, about 100 yards from the sea, some fossil eggs of turtles have been discovered in the hard rock thus formed. The eggs must have been nearly hatched at the time when they perished; for the bones of the young turtle are seen in the interior, with their shape fully developed, the interstices between the bones being entirely filled with grains of sand, which are cemented together, so that when the egg-shells are removed perfect casts of their form remain in stone. In the single specimen here figured (Fig. 82.), which is only five inches in its longest diameter, no less than seven eggs are preserved. †

Fig. 82.



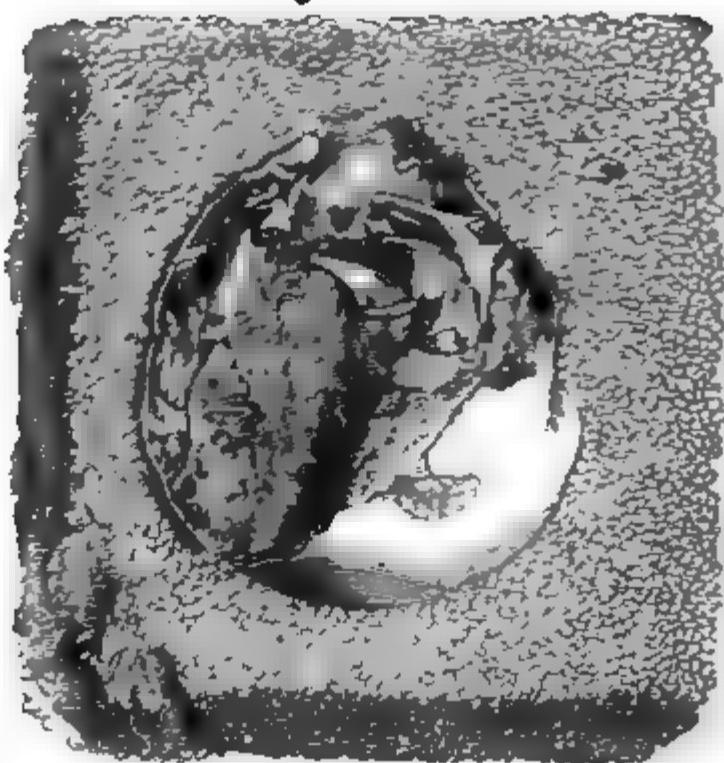
Fossil eggs of Turtles from the Island of Ascension. †

* Quart. Journ. of Lit. Sci., &c. No. xv. p. 172. Oct. 1819.

† This specimen has been presented by Mr. Lonsdale to the Geological Society of London.

‡ The most conspicuous of the bones represented within the

Fig. 82.



One of the eggs in Fig. 82. of the natural size, showing the bones of the fetus which had been nearly hatched.

To explain the state in which they occur fossil, it seems necessary to suppose that after the eggs were almost hatched in the warm sand, a great wave threw upon them so much more sand as to prevent the rays of the sun from penetrating, so that the yolk was

shell in Fig. 82., appear to be the clavicle and coracoid bone. They are hollow; and for this reason resemble, at first sight, the bones of birds rather than of reptiles; for the latter have no medullary cavity. Mr. Owen, of the College of Surgeons, in order to elucidate this point, dissected for me a very young turtle, and found that the exterior portion only of the bones was ossified, the interior being still filled with cartilage. This cartilage soon dried up, and shrank to a mere thread upon the evaporation of the spirits of wine in which the specimen had been preserved, so that in a short time the bones became as empty as those of birds.

chilled and deprived of vitality. The shells were perhaps slightly broken at the same time, so that small grains of sand might gradually be introduced into the interior by water as it percolated through the beach.

Marine testacea. — The aquatic animals and plants which inhabit an estuary are liable, like the trees and land animals which people the alluvial plains of a great river, to be swept from time to time far into the deep; for as a river is perpetually shifting its course, and undermining a portion of its banks with the forests which cover them, so the marine current alters its direction from time to time, and bears away the banks of sand and mud, against which it turns its force. These banks may consist in great measure of shells peculiar to shallow, and sometimes brackish water, which may have been accumulating for centuries, until at length they are carried away and spread out along the bottom of the sea, at a depth at which they could not have lived and multiplied. Thus littoral and estuary shells are more frequently liable even than fresh-water species, to be intermixed with the exuviae of pelagic tribes.

After the storm of February 4. 1831, when several vessels were wrecked in the estuary of the Forth, the current was directed against a bed of oysters with such force, that great heaps of them were thrown *alive* upon the beach, and remained above high-water mark. I collected many of these oysters, as also the common eatable whelks (*buccina*), thrown up with them, and observed that, although still living, their shells were worn by the long attrition of sand which had passed over them as they lay in their native bed, and which had evidently not resulted from the mere action of the tempest by which they were cast ashore.

From these facts we learn that the union of the two parts of a bivalve shell does not prove that it has not been transported to a distance; and when we find shells worn, and with all their prominent parts rubbed off, they may still have been imbedded where they grew.

Burrowing shells. — It sometimes appears extraordinary, when we observe the violence of the breakers on our coast, and see the strength of the current in removing cliffs, and sweeping out new channels, that many tender and fragile shells should inhabit the sea in the immediate vicinity of this turmoil. But a great number of the bivalve testacea, and many also of the turbinated univalves, burrow in sand or mud. The solen and the cardium, for example, which are usually found in shallow water near the shore, pierce through a soft bottom without injury to their shells; and the pholas can drill a cavity through mud of considerable hardness. The species of these and many other tribes can sink, when alarmed, with considerable rapidity, often to the depth of several feet, and can also penetrate upwards again to the surface, if a mass of matter be heaped upon them. The hurricane, therefore, may expend its fury in vain, and may sweep away even the upper part of banks of sand or mud, or may roll pebbles over them, and yet these testacea may remain below secure and uninjured.

Shells become fossil at considerable depths. — I have already stated that, at the depth of 950 fathoms, between Gibraltar and Ceuta, Captain Smith found a gravelly bottom, with fragments of broken shells, carried thither probably from the comparatively shallow parts of the neighbouring straits, through which a powerful current flows. Beds of shelly sand might

here, in the course of ages, be accumulated several thousand feet thick. But, without the aid of the drifting power of a current, shells may accumulate in the spot where they live and die, at great depths from the surface, if sediment be thrown down upon them; for even in our own colder latitudes, the depths at which living marine animals abound is very considerable. Captain Vidal ascertained, by soundings made off Tory Island, on the north-west coast of Ireland, that crustacea, star-fish, and testacea, occurred at various depths between fifty and one hundred fathoms; and he drew up dentalia from the mud of Galway bay, in 230 and 240 *fathoms* water.

The same hydrographer discovered on the Rockall bank large quantities of shells at depths varying from 45 to 190 fathoms. These shells were for the most part pulverized, and evidently recent, as they retained their bright colours. In the same region a bed of fish-bones was observed extending for two miles along the bottom of the sea in eighty and ninety fathoms water. At the eastern extremity also of Rockall bank fish-bones were met with, mingled with pieces of fresh shell, at the depth of 235 fathoms.

Analogous formations are in progress in the submarine tracts extending from the Shetland Isles to the north of Ireland, wherever soundings can be procured. A continuous deposit of sand and mud, replete with broken and entire shells, echini, &c., has been traced for upwards of twenty miles to the eastward of the Faroe Islands, usually at the depth of from forty to one hundred fathoms. In one part of this tract (lat. $61^{\circ} 50'$, long. $6^{\circ} 30'$) fish-bones occur in extraordinary profusion, so that the lead cannot be drawn up without some vertebræ being attached. This

"bone bed," as it was called by our surveyors, is three miles and a half in length, and forty-five fathoms under water, and contains a few shells intermingled with the bones.

In the British seas, the shells and other organic remains lie in soft mud or loose sand and gravel; whereas, in the bed of the Adriatic, Donati found them frequently inclosed in stone of recent origin. This is precisely the difference in character which we might have expected to exist between the British marine formations now in progress, and those of the Adriatic; for calcareous and other mineral springs abound in the Mediterranean and lands adjoining, while they are almost entirely wanting in our own country.

During his survey of the west coast of Africa, Captain Belcher found, by frequent soundings between the twenty-third and twentieth degrees of north latitude, that the bottom of the sea, at the depth of from twenty to about fifty fathoms, consists of sand with a great intermixture of shells, often entire, but sometimes finely comminuted. Between the eleventh and ninth degrees of north latitude, on the same coast, at soundings varying from twenty to about eighty fathoms, he brought up abundance of corals and shells mixed with sand. These also were in some parts entire, and in others worn and broken.

In all these cases, it is only necessary that there should be some deposition of sedimentary matter, however minute, such as may be supplied by rivers draining a continent, or currents preying on a line of cliffs, in order that stratified formations, hundreds of feet in thickness, and replete with organic remains, should result in the course of ages.

But although some deposits may thus extend continuously for a thousand miles or more near certain coasts, the greater part of the bed of the ocean, remote from continents and islands, may very probably receive, at the same time, no new accessions of drift matter, all sediment being intercepted by intervening hollows. Erroneous theories in geology may be formed not only from overlooking the great extent of simultaneous deposits now in progress, but also from the assumption that such formations may be universal or coextensive with the bed of the ocean.

CHAPTER XVIII.

FORMATION OF CORAL REEFS.

Growth of coral chiefly confined to tropical regions — Principal genera of coral-building zoophytes — Their rate of growth — Seldom flourish at greater depths than twenty fathoms — Atolls or annular reefs with lagoons — Maldiva Isles — Origin of the circular form — Coral reefs not based on submerged volcanic craters — Mr. Darwin's theory of subsidence in explanation of circular reefs or atolls — Equally applicable to encircling and barrier reefs — Why the windward side of atolls highest — Subsidence explains why all atolls are nearly on one level — Alternate areas of elevation and subsidence — Probable thickness and shape of coral formations under water according as the motion has been upward or downward, continuous in one direction or oscillatory, slow or rapid, uniform or intermittent — Origin of openings into the lagoons — Size of atolls and barrier reefs — Stratification — Lime whence derived — Supposed increase of calcareous matter in modern epochs controverted — Concluding remarks.

THE powers of the organic creation in modifying the form and structure of the earth's crust, are most conspicuously displayed in the labours of the coral animals. We may compare the operation of these zoophytes in the ocean, to the effects produced on a smaller scale upon the land by the plants which generate peat. In the case of the Sphagnum, the upper part vegetates

while the lower portion is entering into a mineral mass, in which the traces of organization remain when life has entirely ceased. In corals, in like manner, the more durable materials of the generation that has passed away serve as the foundation on which the living animals continue to rear a similar structure.

The stony part of the lamelliform zoophyte may be likened to an internal skeleton ; for it is always more or less surrounded by a soft animal substance capable of expanding itself ; yet, when alarmed, it has the power of contracting and drawing itself almost entirely into the cells and hollows of the hard coral. Although oftentimes beautifully coloured in their own element, the soft parts become when taken from the sea nothing more in appearance than a brown slime spread over the stony nucleus.*

The growth of those corals which form reefs of solid stone is entirely confined to the warmer regions of the globe, rarely extending beyond the tropics above two or three degrees, except under peculiar circumstances, as in the Bermuda islands, in lat. 32° N., where the Atlantic is warmed by the gulf stream. The Pacific Ocean, throughout a space comprehended between the thirtieth parallels of latitude on each side of the equator, is extremely productive of coral ; as also are the Arabian and Persian Gulfs. Coral is also abundant in the sea between the coast of Malabar and the island of Madagascar. Flinders describes a reef of coral on the east coast of New Holland as having a length of nearly 1000 miles, and as being in one part

* Ehrenberg, Nat. und Bild. der Coralleninseln, &c., Berlin, 1834.

unbroken for a distance of 350 miles. Some groups of coral islands in the Pacific are from 1100 to 1200 miles in length, by 300 or 400 in breadth, as the Dangerous Archipelago, for example, and that called Radack by Kotzebue; but the islands within these spaces are always small points, and often very thinly sown.

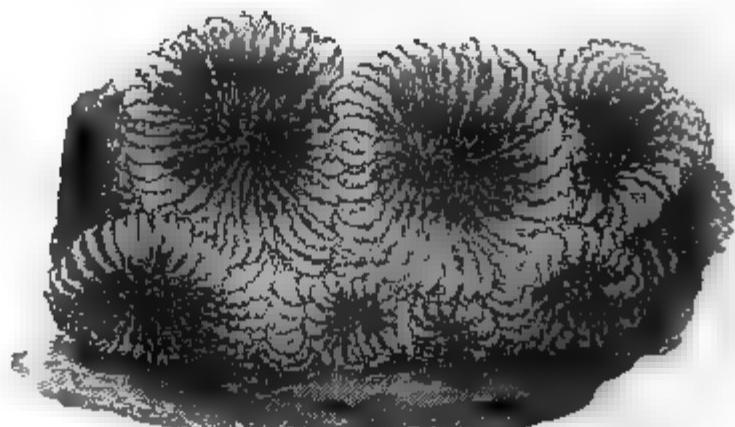
Fig. 64.



Meandrina labyrinthica, Lam.
pors, *Caryophyllia*, and *Meandrina*.

Of the numerous species of zoophytes which are engaged in the production of coral banks, some of the most common belong to the Lamarckian genera *Astrea*, *Porites*, *Madrepora*, *Mille-*

Fig. 25.



Astrea dipsacea, Lam.

Genera of Zoophytes most common in coral reefs.

Fig. 86.

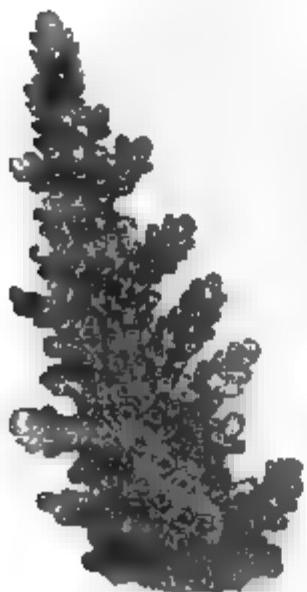
*Extremity of branch of
Madrepora muricata, Lin.*

Fig. 87.

*Caryophyllia fastigiata, Lam.*

Fig. 88.

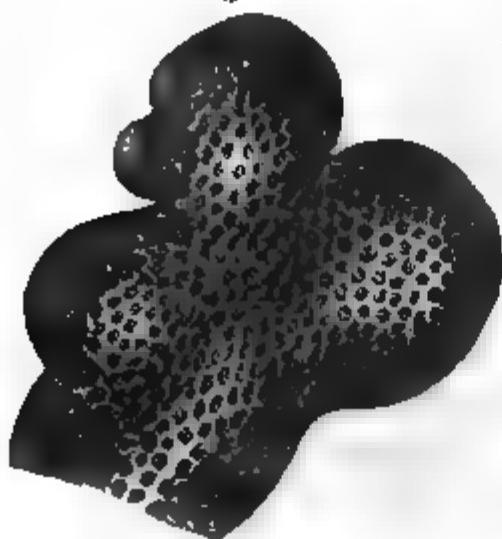
*Porites clavaria, Lam.*

Fig. 89.

*Oculina hirsuta, Lam.*

Rate of the growth of coral. — Very different opinions have been entertained in regard to the rate at which coral reefs increase. In Captain Beechey's late expedition to the Pacific, no positive information could be obtained of any channel having been filled up within a given period ; and it seems established, that several reefs had remained, for more than half a century, at about the same depth from the surface.

Ehrenberg also questions the fact of channels and harbours having been closed up in the Red Sea by the rapid increase of coral limestone. He supposes the notion to have arisen from the circumstance of havens having been occasionally filled up in some places with coral sand, in others with large quantities of ballast of coral rock thrown down from vessels.

The natives of the Bermuda Islands point out certain corals now growing in the sea, which, according to tradition, have been living in the same spots for centuries. It is supposed that some of them may vie in age with the most ancient trees of Europe. Ehrenberg also observed single corals of the genera *Meandrina* and *Favia*, having a globular form, from six to nine feet in diameter, "which must (he says) be of immense antiquity, probably several thousand years old, so that Pharaoh may have looked upon these same individuals in the Red Sea." * They certainly imply, as he remarks, that the reef on which they grow has increased at a very slow rate. After collecting more than 100 species, he found none of them covered with parasitic zoophytes, nor any instance of a living coral growing on another living coral. To this repulsive power which they exert whilst living,

* Ehrenberg, as before cited, p. 367.

against all others of their own class, we owe the beautiful symmetry of some large Meandrinæ, and other species which adorn our museums. Yet balani and serpulæ can attach themselves to living corals, and holes are excavated in them by saxicavous mollusca. On the other hand, an oyster which cannot have been more than two years old when taken, is preserved in the museum of the Bristol Institution, enveloped by a dense coral, a species of Agaricia, weighing 2lb. 9oz.* At the island called Taaopoto, in the South Pacific, the anchor of a ship, wrecked about 50 years before, was observed in seven fathom water, still preserving its original form, but entirely incrusted by coral.†

This fact would seem to imply a slow rate of augmentation; but to form a correct estimate of the average rate must be very difficult, since it must vary not only according to the species of coral, but according to the circumstances under which each species may be placed; such, for example, as the depth from the surface, the quantity of light, the temperature of the water, its freedom from sand or mud, or the absence or presence of breakers, which is favourable to the growth of some kinds and is fatal to that of others.

It should also be observed that the apparent stationary condition of some coral reefs, which according to Beechey have remained for centuries at the same depth under water, may be due to subsidence, the upward growth of the coral having been just sufficient to keep pace with the sinking of the solid foundation on which the zoophytes have built. We shall afterwards see how far this hypothesis is borne out by other evidence in the regions of annular reefs or atolls.

* Stutchbury, West of England Journal, No. i. p. 51.

† Ibid. p. 49.

It must not be supposed that the calcareous masses termed coral reefs are exclusively the work of zoophytes; a great variety of shells, and, among them, some of the largest and heaviest of known species, contribute to augment the mass. In the South Pacific, great beds of oysters, muscles, *pinnæ marinae*, *chama* (or *tridacnae*), and other shells, cover in profusion almost every reef; and, on the beach of coral islands, are seen the shells of echini and broken fragments of crustaceous animals. Large shoals of fish are also discernible through the clear blue water, and their teeth and hard palates cannot fail to be often preserved, although their soft cartilaginous bones may decay.

It was the opinion of the German naturalist Forster, in 1780, after his voyage round the world with Captain Cook, that coral animals had the power of building up steep and almost perpendicular walls from great depths in the sea, a notion afterwards adopted by Captain Flinders and others; but it is now very generally believed that these zoophytes cannot live in water of great depths.

Mr. Darwin has come to the conclusion, that those species which are most effective in the construction of reefs, rarely flourish at a greater depth than 20 fathoms, or 120 feet. Ehrenberg, after devoting more than a year to the examination of the corals of the Red Sea, conceives that they do not grow there at depths exceeding eight fathoms *; although there, are various species of zoophytes, and among them some which are provided with calcareous as well as horny stems, which live in much deeper water, even in some cases to a depth of 180 fathoms. MM.

* Ehrenberg, Nat. und Bild. der Coralleninseln, &c., Berlin, 1834.

Quoy and Gaimard were certainly much mistaken in thinking that the species which contribute most actively to the formation of solid masses, do not grow in water beyond the depth of four or five fathoms. It has been suggested that the branched madrepores, which live at the greatest depth, may form the first foundation of a reef, and possibly raise a platform on which other species may afterwards build *; but there is at present no proof of reefs having originated in this manner.

There is every variety of form in coral reefs, but the most remarkable and numerous in the Pacific consist of circular or oval strips of dry land, enclosing a shallow lake or lagoon of still water, in which zoophytes and mollusca abound. These annular reefs just raise themselves above the level of the sea, and are surrounded by a deep and often unfathomable ocean.

In the annexed cut (Fig. 90.), one of these circular

Fig. 90



View of Whitsunday Island. (Capt. Beechey.) †

* Journ. of Roy. Geograph. Soc. 1831, p. 218.

† Voyage to the Pacific, &c. in 1826-28.

islands is represented, just rising above the waves, covered with the cocoa-nut and other trees, and inclosing within a lagoon of tranquil water.

The accompanying section will enable the reader to comprehend the usual form of such islands. (Fig. 91.)

Fig. 91.



Section of a Coral Island.

a, a, Habitable part of the Island, consisting of a strip of coral, inclosing the lagoon.

b, b, The lagoon.

The subjoined cut (Fig. 92.) exhibits a small part of the section of a coral island on a larger scale.

Fig. 92.



Section of part of a Coral Island.

a, b, Habitable part of the island.

b, c, Slope of the side of the island, plunging at an angle of forty-five to the depth of fifteen hundred feet.

c, c, Part of the lagoon.

d, d, Knolls of coral in the lagoon, with overhanging masses of coral resembling the capitals of columns.

Of thirty-two of these coral islands visited by Beechey in his voyage to the Pacific, twenty-nine had lagoons in their centres. The largest was 30 miles in diameter, and the smallest less than a mile. All were increasing their dimensions by the active operations of the lithophytes, which appeared to be gradually extending and bringing the immersed parts of their structure to the surface. The scene presented by these annular reefs is equally striking for its singularity and beauty. A strip of land a few hundred

yards wide is covered by lofty cocoa-nut trees, above which is the blue vault of heaven. This band of verdure is bounded by a beach of glittering white sand, the outer margin of which is encircled with a ring of snow-white breakers, beyond which are the dark heaving waters of the ocean. The inner beach incloses the still clear water of the lagoon, resting in its greater part on white sand, and, when illuminated by a vertical sun, of a most vivid green.* Certain species of zoophytes abound most in the lagoon, others on the exterior margin, where there is a great surf. "The ocean," says Mr. Darwin, "throwing its breakers on these outer shores, appears an invincible enemy, yet we see it resisted and even conquered by means which at first seem most weak and inefficient. No periods of repose are granted, and the long swell caused by the steady action of the trade wind never ceases. The breakers exceed in violence those of our temperate regions, and it is impossible to behold them without feeling a conviction that rocks of granite or quartz would ultimately yield and be demolished by such irresistible forces. Yet these low insignificant coral islets stand and are victorious, for here another power, as antagonist to the former, takes part in the contest. The organic forces separate the atoms of carbonate of lime one by one from the foaming breakers, and unite them into a symmetrical structure; myriads of architects are at work night and day, month after month, and we see their soft and gelatinous bodies through the agency of the vital laws conquering the great mechanical power of the waves of an ocean, which neither the art of

* Darwin's Journal, &c. p. 540.

man, nor the inanimate works of nature could successfully resist." *

As the coral animals require to be continually immersed in salt water, they cannot raise themselves by their own efforts above the level of the lowest tides. The manner in which the reefs are converted into islands above the level of the sea is thus described by Chamisso, a naturalist who accompanied Kotzebue in his voyages : — " When the reef," says he, " is of such a height that it remains almost dry at low water the corals leave off building. Above this line a continuous mass of solid stone is seen composed of the shells of mollusks and echini, with their broken-off prickles and fragments of coral, united by calcareous sand, produced by the pulverization of shells. The heat of the sun often penetrates the mass of stone when it is dry, so that it splits in many places, and the force of the waves is thereby enabled to separate and lift blocks of coral, frequently six feet long and three or four in thickness, and throw them upon the reef, by which means the ridge becomes at length so high that it is covered only during some seasons of the year by the spring tides. After this the calcareous sand lies undisturbed, and offers to the seeds of trees and plants cast upon it by the waves a soil upon which they rapidly grow, to overshadow its dazzling white surface. Entire trunks of trees, which are carried by the rivers from other countries and islands, find here, at length, a resting-place after their long wanderings: with these come some small animals, such as insects and lizards, as the first inhabitants. Even before the trees form a wood, the sea-birds nestle here; strayed land-birds take

* Darwin's Journal, &c. pp. 547, 548.

refuge in the bushes; and, at a much later period, when the work has been long since completed, man appears and builds his hut on the fruitful soil." *

In the above description the solid stone is stated to consist of shell, and coral, united by sand; but masses of very compact limestone are also found even in the uppermost and newest parts of the reef, such as could only have been produced by chemical precipitation.

In these instances the carbonate of lime may have been derived from the decomposition of corals and testacea; for when the animal matter undergoes putre-laction, the calcareous residuum must be set free under circumstances very favourable to precipitation, especially when there are other calcareous substances, such as shells and corals on which it may be deposited. Thus organic bodies may be inclosed in a solid cement, and become portions of rocky masses. †

The width of the circular strip of dead coral forming the islands explored by Captain Beechey, exceeded in no instance half a mile from the usual wash of the sea to the edge of the lagoon, and, in general, was only about three or four hundred yards. ‡ The depth of the lagoons is various; in some, entered by Captain Beechey, it was from twenty to thirty-eight fathoms.

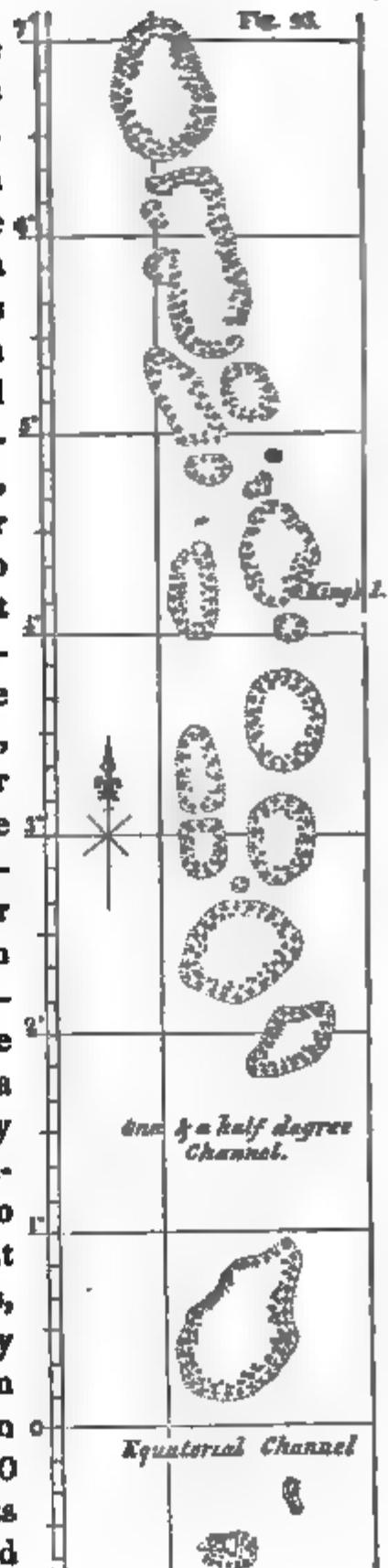
The two other peculiarities which are most characteristic of the annular reef or atoll is first, that the strip of dead coral is invariably highest on the windward side, and secondly that there is very generally an opening at some point in the reef affording a narrow passage, often of considerable depth, from the sea into the lagoon.

* Kotzebue's Voyages, 1815-18, vol. iii. pp. 331—333.

† Stuchbury, West of Eng. Journ., No. i. p. 50.

‡ Captain Beechey, part i. p. 188.

Maldive and Laccadive Isles.—The chain of reefs and islets called the Maldivas (see fig. 93.), situated in the Indian Ocean, to the south-west of Malabar, form a chain 480 geographical miles in length, running due north and south. It is composed throughout of a series of circular assemblages of islets, all formed of coral, the larger groups being from forty to ninety miles in their longest diameter. Captain Hornburgh, whose chart of these islands is subjoined, states, that outside of each circle or *atoll*, as it is termed, there are coral reefs sometimes extending to the distance of two or three miles, beyond which there are no soundings at immense depths. But in the centre of each atoll there is a lagoon from fifteen to forty fathoms deep. In the channels between the atolls, no soundings were obtained at the depth of 150 fathoms, but I understand that they have since been found, in some places, during Captain Moresby's survey, within 200 fathoms. Each atoll consists of a ring of islands instead



of one continuous and circular reef, there being sometimes more than 100 islands in one atoll, each island varying from half a mile to two miles in length. They are composed of sandstone formed of broken shells and corals, such as may be obtained in a loose state from the beach, and which is seen when exposed for a few days to the air to become hardened. The sandstone is sometimes observed to be an aggregate of broken shells, corals, pieces of wood, and shells of the cocoa-nut.*

The Laccadive islands run in the same line with the Maldivas, on the north, as do the isles of the Chagos Archipelago, on the south; so that these may be continuations of the same chain of submerged mountains, crested in a similar manner by coral limestones.

Origin of the circular form — not volcanic. — The circular and oval shape of so many reefs, each having a lagoon in the centre, and being surrounded on all sides by a deep ocean, naturally suggested the idea that they were nothing more than the crests of submarine volcanic craters overgrown by coral; and this theory I myself advocated in former editions. Although I am now about to show that it must be abandoned, it may still be instructive to point out the grounds on which it was formerly embraced. In the first place it had been remarked that there were many active volcanos in the coral region of the Pacific, and that in some places, as in Gambier's group, rocks composed of porous lava rise up in a lagoon bordered by a circular reef, just as the two cones of eruption called the Kamenis, have made their appearance in the times of

* Captain Moresby on the Maldivas, Journ. Roy. Geograph. Soc. vol. v. part ii. p. 400

history within the circular gulf of Santorin.* It was also observed that as in S. Shetland, Barren Island, and others of volcanic origin, there is one narrow breach in the walls of the outer cone by which ships may enter a circular gulf, so in like manner is there often a single deep passage leading into the lagoon of a coral island, the lagoon itself seeming to represent the hollow or gulph just as the ring of dry coral recalls the rim of a volcanic crater.

Another argument which I adduced when formerly defending this doctrine was derived from Ehrenberg's statement, that some banks of coral in the Red Sea were square, while many others were ribbon-like strips, with flat tops, and without lagoons. Since, therefore, all the genera and many of the species of zoophytes in the Red Sea agreed with those which elsewhere construct lagoon islands, it followed that the stone-making zoophytes are not guided by their own instinct in the formation of annular reefs, but that this peculiar shape and the position of such reefs in the midst of a deep ocean must depend on the outline of the submarine bottom, which nothing else in nature resembles but the crater of a lofty submerged volcanic cone. The enormous size, it is true, of some atolls made it necessary for me to ascribe to the craters of many submarine volcanos a magnitude which was startling, and which had often been appealed to as a serious objection to the volcanic theory.

May be explained by subsidence. — Mr. Darwin, after examining a variety of coral formations in different parts of the globe, was induced to reject the opinion that their shape represented the form of the original

* See Vol. II. p. 282.

bottom. Instead of admitting that the ring of dead coral rested on a circular or oval ridge of rock, or that the lagoon corresponded to a pre-existing cavity, he advanced a new opinion, which must, at first sight, seem paradoxical in the extreme; namely, that the lagoon is precisely in the place which the top of a shoal, or, in other cases, the highest part of a mountainous island, once occupied. The following is a brief sketch of the facts and arguments in favour of this new view.

Besides those rings of dry coral which inclose lagoons, there are others having a similar form and structure which encircle lofty islands. Of the latter kind is Vanikoro, celebrated on account of the shipwreck of La Peyrouse, where the coral reef runs at the distance of two or three miles from the shore, the channel between it and the land having a general depth of between 200 and 300 feet. This channel, therefore, is analogous to a lagoon, but with an island standing in the middle like a picture in its frame. In like manner in Tahiti we see a mountainous land with every where round its margin a lake or zone of smooth salt water, separated from the ocean by an encircling reef of coral, on which a line of breakers are always foaming. So also New Caledonia, a long narrow island east of New Holland, in which the rocks are granitic, is surrounded by a reef which runs for a length of 400 miles. This reef encompasses not only the island itself, but a ridge of rocks which are prolonged in the same direction beneath the sea. No one, therefore, will contend for a moment that in this case the corals are based upon the rim of a volcanic crater, in the middle of which stands a mountain or island of granite.

The great barrier reef, already mentioned as run-

ning parallel to the north-east coast of Australia for nearly 1000 miles, is another most remarkable example of a long strip of coral running parallel to a coast. Its distance from the mainland varies from twenty to seventy miles, and the depth of the great arm of the sea thus inclosed is usually between ten and twenty fathoms, but towards one end from forty to sixty.

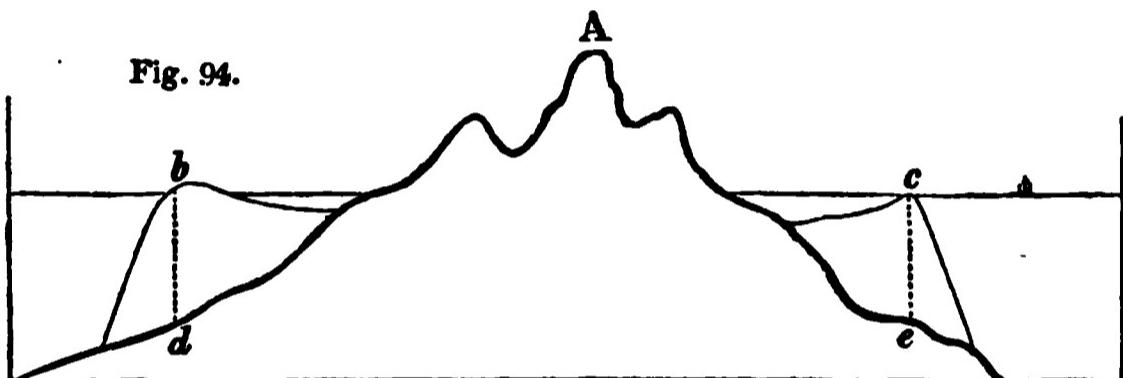
Two classes of reefs, therefore, have now been considered; first, the atoll, and, secondly, the encircling and barrier reef, all agreeing perfectly in structure, and the sole difference lying in the absence in the case of the atoll of all land, and its presence in the other cases whether as an encircled island or continent bordered by a barrier. But there is still a third class of reefs, called by Mr. Darwin "fringing reefs," which approach much nearer the land than those of the encircling and barrier class, and which indeed so nearly touch the coast as to leave nothing in the intervening space resembling a lagoon. "That these reefs are not attached quite close to the shore appears to be the result of two causes; first, that the water immediately adjoining the beach is rendered turbid by the surf, and therefore injurious to all zoophytes; and, secondly, that the larger and efficient kinds only flourish on the outer edge amidst the breakers of the open sea." *

It will at once be conceded that there is so much analogy between the form and position of the strip of coral in the atoll, and in the encircling and barrier reef, that no explanation can be satisfactory which does not include the whole. If we turn in the first place to the encircling and barrier reefs, and endeavour to explain

* Darwin's Journal, p. 557.

how the zoophytes could have found a bottom on which to begin to build, we are met at once with a great difficulty. It is a general fact, long since remarked by Dampier, that high land and deep seas go together. In other words, steep mountains coming down abruptly to the sea-shore are generally continued with the same slope beneath the water. But where the reef, as at *b* and *c* (fig. 94.), is distant several miles from a steep coast, a line drawn perpendicularly downwards from its outer edges *b c* to the fundamental rock *d e*, must descend to a depth exceeding by several thousand feet

Fig. 94.

*Supposed section of an Island with an encircling reef of Coral.*

A, The island.

b c, Highest points of the encircling reef between which and the coast is seen a space occupied by still water.

the limits at which the efficient stone-building corals can exist, for we have seen that they cease to grow in water which is more than 120 feet deep. That the original rock immediately beneath the points *b c* is actually as far from the surface as *d e*, is not merely inferred from Dampier's rule, but confirmed by the fact, that immediately outside the reef, soundings are either not met with at all, or only at enormous depths. In short, the ocean is as deep there as might have been anticipated in the neighbourhood of a bold coast ; and it is obviously the presence of the coral alone which has given rise to the anomalous existence of

shallow water on the reef and between it and the land.

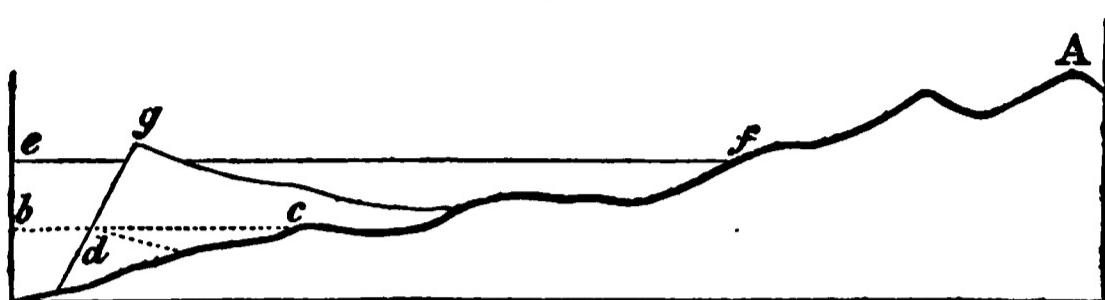
To explain the phenomena above described, Mr. Darwin supposes that the coral-forming polypi begin to build in water of a moderate depth, and, while they are yet at work, the bottom of the sea subsides gradually, so that the foundation of their edifice is carried downwards at the same time that they are raising the superstructure. If, therefore, the rate of subsidence be not too rapid, the growing coral will continue to build up to the surface ; the mass always gaining in height above its original base, but remaining in other respects in the same position. Not so with the land : each inch lost is irreclaimably gone ; as it sinks the water gains foot by foot on the shore, till in many cases the highest peak of the original island disappears. What was before land is then occupied by the lagoon, the position of the encircling coral remaining unaltered, with the exception of a slight contraction of its dimensions.

In this manner are encircling reefs and atolls produced ; and in confirmation of his theory Mr. Darwin has pointed out examples which illustrate every intermediate state, from that of lofty islands, such as Otaheite, encircled by coral, to that of Gambier's group, where a few peaks only of land rise out of a lagoon, and, lastly, to the perfect atoll, having a lagoon several hundred feet deep, surrounded by a reef rising steeply from an unfathomed ocean.

If we embrace these views, it is clear, that in regions of growing coral a similar subsidence must give rise to barrier reefs along the shores of a continent. Thus suppose A (fig. 95.) to represent the north-east portion of Australia, and *b c* the ancient level of the sea, when

the coral reef *d* was formed. If the land sink so that it is submerged more and more, the sea must at

Fig. 95.



length stand at the level *e f*, the reef in the mean time having been enlarged and raised to the point *g*. The distance between the shore *f*, and the barrier reef *g*, is now much greater than originally between the shore *c*, and the reef *d*, and the longer the subsidence continues the farther will the coast of the mainland recede.

When the first edition of this work appeared in 1831, several years before Mr. Darwin had investigated the facts on which his theory is founded, I had come to the opinion that the land was subsiding at the bottom of those parts of the Pacific where atolls are numerous, although I failed to perceive that such a subsidence, if conceded, would equally solve the enigma as to the form both of annular and barrier reefs.

I shall cite the passage referred to, as published by me in 1831 :— “ It is a remarkable circumstance that there should be so vast an area in Eastern Oceanica, studded with minute islands, without one single spot where there is a wider extent of land than belongs to such islands as Otaheite, Owhyhee, and a few others, which either have been or are still the seats of active volcanos. If an equilibrium only were maintained between the upheaving and depressing force of earthquakes, large islands would very soon be formed in

the Pacific; for, in that case, the growth of limestone; the flowing of lava, and the ejection of volcanic ashes, would combine with the upheaving force to form new land.

"Suppose a shoal, 600 miles in length, to sink fifteen feet, and then to remain unmoved for a thousand years; during that interval the growing coral may again approach the surface. Then let the mass be re-elevated fifteen feet, so that the original reef is restored to its former position: in this case, the new coral formed since the first subsidence will constitute an island 600 miles long. An analogous result would have occurred if a lava current fifteen feet thick had overflowed the submerged reef. The absence, therefore, of more extensive tracts of land in the Pacific, seems to show that the amount of subsidence by earthquakes exceeds, in that quarter of the globe, at present, the elevation due to the same cause." *

Another proof also of subsidence derived from the structure of atolls, was pointed out by me in the following passage in all former editions. "The low coral islands of the Pacific," says Captain Beechey, "follow one general rule in having their windward side higher and more perfect than the other. At Gambier and Matilda islands this inequality is very conspicuous, the weather side of both being wooded, and of the former inhabited, while the other sides are from twenty to thirty feet under water; where, however, they may be perceived to be equally narrow and well defined. It is on the leeward side also that the entrances into the lagoons occur; and although they may sometimes be situated on a side that runs in the

* See Principles of Geol., 1st ed. vol. II. p. 296.

direction of the wind, as at Bow Island, yet there are none to windward." These observations of Captain Beechey accord with those which Captain Horsburgh, and other hydrographers, have made in regard to the coral islands of other seas. From this fortunate circumstance ships can enter and sail out with ease; whereas if the narrow inlets were to windward, vessels which once entered might not succeed for months in making their way out again. The well-known security of many of these harbours depends entirely on this fortunate peculiarity in their structure.

" In what manner is this singular conformation to be accounted for? The action of the waves is seen to be the cause of the superior elevation of some reefs on their windward sides, where sand and large masses of coral rock are thrown up by the breakers; but there is a variety of cases where this cause alone is inadequate to solve the problem; for reefs submerged at considerable depths, where the movements of the sea cannot exert much power, have, nevertheless, the same conformation, the leeward being much lower than the windward side.*

" I am informed by Captain King, that, on examining the reefs called Rowley Shoals, which lie off the north-west coast of Australia, where the east and west monsoons prevail alternately, he found the open side of one crescent-shaped reef, the Impérieuse, turned to the east, and of another, the Mermaid, turned to the west; while a third oval reef, of the same group, was entirely submerged. This want of conformity is exactly what we should expect, where the winds vary periodically.

* *Voyage to the Pacific, &c., p. 189.*

"It seems impossible to refer the phenomenon now under consideration to any original uniformity in the configuration of submarine volcanos, on the summits of which we may suppose the coral reefs to grow; for although it is very common for craters to be broken down on one side only, we cannot imagine any cause that should breach them all in the same direction. But the difficulty will, perhaps, be removed, if we call in another part of the volcanic agency — subsidence by earthquakes. Suppose the windward barrier to have been raised by the mechanical action of the waves to the height of two or three yards above the wall on the leeward side, and then the whole island to sink down a few fathoms, the appearances described would then be presented by the submerged reef. A repetition of such operations, by the alternate elevation and depression of the same mass (an hypothesis strictly conformable to analogy), might produce still greater inequality in the two sides, especially as the violent efflux of the tide has probably a strong tendency to check the accumulation of the more tender corals on the leeward reef; while the action of the breakers contributes to raise the windward barrier."*

Previously to my advertizing to the signs above enumerated of a downward movement in the bed of the ocean, Dr. MacCulloch, Captain Beechey, and many other writers had shown that masses of recent coral had been laid dry at various heights above the sea-level, both in the Red Sea, the islands of the Pacific, and in the East and West Indies. After describing thirty-two coral islands in the Pacific, Captain Beechey mentioned that they were all formed of living coral

* See *Principles of Geol.* 1st ed. vol. ii. p. 293.

except one, which, although of coral formation, was raised about seventy or eighty feet above the level of the sea, and was encompassed by a reef of living coral. It is called Elizabeth or Henderson's Island, and is five miles in length by one in breadth. It has a flat surface, and, on all sides, except the north, is bounded by perpendicular cliffs about fifty feet high, composed entirely of dead coral, more or less porous, honey-combed at the surface, and hardening into a compact calcareous mass, which possesses the fracture of secondary limestone, and has a species of millepore interspersed through it. These cliffs are considerably undermined by the action of the waves, and some of them appear on the eve of precipitating their superincumbent weight into the sea. Those which are less

Fig. 96.

Elizabeth, or Henderson's Island.

injured in this way present no alternate ridges or indication of the different levels which the sea might have occupied at different periods; but a smooth surface, as if the island, which has probably been raised by volcanic agency, had been forced up by one great subterraneous convulsion.* At the distance of a few hundred yards from this island, no bottom could be gained with 200 fathoms of line.

It will be seen, from the annexed sketch, communicated to me by Lieutenant Smith, of the *Blossom*, that the trees came down to the beach towards the centre

* Beechey's *Voyage to the Pacific, &c.*, p. 46.

of the island; a break at first sight resembling the openings which usually lead into lagoons: but the trees stand on a steep slope, and no hollow of an ancient lagoon was perceived.

Beechey also remarks, that the surface of Henderson's Island is flat, and that in Queen Charlotte's Island, one of the same group, but under water, there was no lagoon, the coral having grown up every where to one level. The probable cause of this obliteration of the central basin or lagoon will be considered in the sequel.

That the bed of the Pacific and Indian oceans, where atolls are frequent, must have been sinking for ages, might be inferred, says Mr. Darwin, from simply reflecting on two facts; first, that the efficient coral-building zoophytes do not flourish in the ocean at a greater depth than 120 feet; and, secondly, that there are spaces occupying areas of many hundred thousand square miles, where all the islands consist of coral, and yet none of which rise to a greater height than may be accounted for by the action of the winds and waves on broken and triturated coral. Were we to take for granted that the floor of the ocean had remained stationary from the time when the coral began to grow, we should be compelled to assume that an incredible number of submarine mountains of vast height (for the ocean is always deep, and often unfathomable between the different atolls,) had all come to within 120 feet of the surface, and yet no one mountain had risen above water. But no sooner do we admit the theory of subsidence, than this great difficulty vanishes. However varied may have been the altitude of different islands, or the separate peaks

of particular mountain-chains, all may have been reduced to one uniform level by the gradual submergence of the loftiest points, and the additions made to the calcareous cappings of the less elevated summits as they subsided to great depths.

Assuming, then, that the presence of lagoon islands, and of encircling and barrier reefs, afford proofs of the sinking of the ground, and that skirting reefs and uplifted banks of shells and corals furnish evidence of the rising of the same, Mr. Darwin next arrived at the important generalization, that the Pacific and Indian seas, and some of the lands which border them, might be divided into areas of elevation and areas of subsidence, which occur alternately. Thus, if we commence with the western shores of South America, we find signs of recent elevation, not attested indeed by coral formations, which are wanting there, but by upraised banks of marine shells. Proceeding westward, we must then traverse a deep ocean without islands, until we come to a band of *atolls* and encircled islands, including the Dangerous and Society archipelagos, and constituting an area of subsidence more than 4000 miles long and 600 broad. Still farther, in the same direction, we reach the chain of islands to which the New Hebrides, Solomon, and New Ireland belong, where fringing reefs and masses of elevated coral indicate another area of upheaval. Again, to the westward of the New Hebrides we meet with the encircling reef of New Caledonia and the great Australian barrier, implying a second area of subsidence.

Having laid before the reader this brief analysis of Mr. Darwin's theory, I shall next endeavour to trace out some of the other natural consequences to which

it appears to me to lead.* It is clear that the form and structure of reefs will be greatly modified according to the direction and rate of the movement, as whether it has been upward or downward, always in one direction, or oscillatory, slow or rapid, intermittent or uniform.

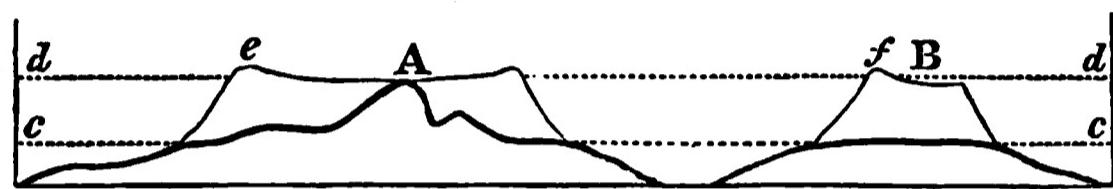
Subsidence.—When we consider that the space over which atolls are scattered in Polynesia and the Indian oceans, may be compared to the whole continent of Asia, we cannot but infer from analogy that the differences in level in so vast an area, amounted, before the beginning of any subsidence, to 5000, 10,000, or even a greater number of feet. Whatever was the difference in height between the loftiest and lowest of the original mountains on which the different atolls are based, that difference must represent the thickness of coral which has now reduced all of them to one level. Flinders, therefore, by no means exaggerated the volume of the limestone, which he conceived to have been the work of coral animals; he was merely mistaken as to the manner in which they were enabled to raise up reefs from the bottom of an unfathomed ocean.

If we reflect on the consequences of a downward movement, it will appear that, provided the bottom does not sink too fast to allow the zoophytes to build upwards at the same pace, the thickness of coral will be great in proportion to the rapidity of subsidence, so that if one area sinks two feet while another sinks one,

* I know not how far the conclusions deduced in the remainder of this chapter may agree with those at which Mr. Darwin has arrived, and which he will explain in detail in his forthcoming work on Coral Formations.

the mass of coral in the first area will be double that in the second. But where the downward movement has been uniform, the thickness of the limestone will be the same whether the reef originally encircled a shoal or a lofty island. Thus, for example, when the foundations of the atolls A, B (Fig. 97.) were laid, the sea being at the level *c*, A was an encircled island

Fig. 97.



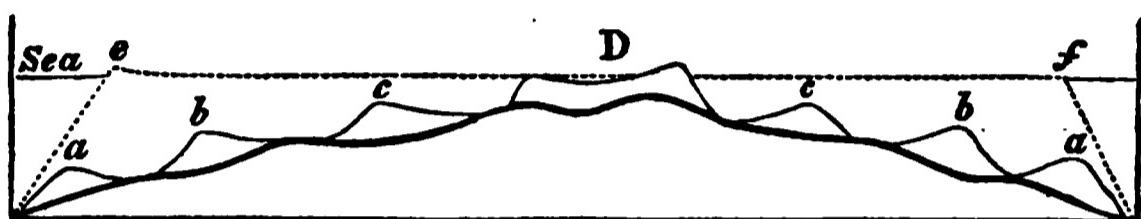
2000 feet high, and B a shoal only dry at low water ; but the land having been sinking for centuries, so that the sea now stands at the level *d*, the mass of coral is of equal thickness, namely about 2000 feet, beneath the points *e* and *f*. It is in the centre only of the two atolls that there is a great comparative difference in the thickness of coral.

If the rate of subsidence be uniform and such as to carry down the bottom faster than the corals can raise it by their upward growth, there will then be no encircling reef or atoll, but the island or continent will be submerged more and more, having first become incrusted over with coralline limestone, which will form a dense or thin coating according as the movement has been slow or rapid.

On the other hand, if the motion be not uniform, and yet the ground sink upon the whole faster than the corals can grow upwards, there may be numerous rings of coral formed, as represented at *a*, *b*, *c* in the section (Fig. 98.), these rings marking the periods when the downward movement was slow enough to allow of

a considerable growth of coral, first at *a*, then at *b*, and then at *c*; the intervening spaces marking periods of rapid subsidence which only allowed time for the growth of a very thin crust (if any) of coral. At length, if the rate of sinking diminish, the small atoll *D* may be formed, whereas if the same land had gone down more slowly, that is to say, at such a rate as that the move-

Fig. 98.



ment never exceeded in vertical amount that which the growing coral can keep pace with, then, instead of the rings *a*, *b*, *c*, the large atoll *e f* would be raised on the same base.

On the other hand, if land be rising with an irregular or intermittent motion, rings of coral like those represented at *a*, *b*, *c* (Fig. 98.), might also be formed, the only difference being, that in that case the upper rings will be first produced at periods when the elevation proceeds slowly, and then the lower ones.

If the movement be both elevatory and uniform the shore will be constantly bordered by a fringing reef, and the surface of the land, as it rises from the sea, will be overspread with corals. This covering, however, will not in all likelihood remain continuous, because it will be exposed to the denuding action of the waves during upheaval, and after emergence may become concealed under lava or volcanic matter.

The island of Pulo Nias, off Sumatra, which is about 3000 feet high, is described by Dr. Jack as being overspread by coral and large shells of the *Chama* (*Tridacna*) *gigas*, which rest on quartzose and arena-

ceous rocks, at various levels from the sea-coast to the summit of the highest hills.*

Oscillations.—We may next consider the effects of an oscillatory movement like that of the ground on which stands the Temple of Serapis, near Naples, which has twice risen and twice subsided within the last 2000 years. † In former editions I stated, that if in a region of atolls the alternate upward and downward movements balance each other, large masses of coral will be raised above the level of the sea, and islands, such as Henderson's before mentioned, which is about sixty feet or more in height, will appear, or like the Tonga and Hapai isles, which stand from ten to thirty feet above the level of the water.

We learn from the description of Henderson's Island just alluded to, that an upraised mass of coral may present cliffs, undermined by the waves, and surrounded by a coral reef. In such cases, if oscillations be repeated, a most complicated structure must result, one reef serving as the nucleus of another, and calcareous sand, the produce of denudation, alternating with corals which will remain entire and in the position in which they have grown.

It was observed that Henderson's and Queen Charlotte's islands are flat-topped, and exhibit no traces of a lagoon. The former, although about sixty or seventy feet high, stands in the midst of a region of atolls, and exhibits, therefore, an instance of partial upheaval in an area of subsidence. We may presume that, after sinking for ages, it was at length upheaved. Now when the descending movement was relaxed and in the

* Geol. Trans., second series, vol. i. p. 397.

† See Vol. II. p. 899.

course of being converted into an ascending one, the ground would probably remain for a long season almost stationary, in which case the corals within the lagoon would build up to the surface, and reach the level already attained by those on the margin of the reef. In this manner the lagoon would be effaced, and the island acquire a flat summit.

Openings into the lagoons. — In the general description of atolls and encircling reefs, it was mentioned that there is almost always a deep narrow passage opening into the lagoon, or into the still water between the reef and the shore, which is kept open by the efflux of the sea as the tide goes down.

The origin of this channel must, according to the theory before advocated, be traced back to causes which were in action during the existence of the encircling reef, and when an island or mountain top rose within it, for such a reef precedes the atoll in the order of formation. Now in those islands in the Pacific, which are large enough to feed small rivers, there is generally an opening or channel in the surrounding coral reef at the point where the stream of fresh water enters the sea. The depth of these channels rarely exceeds twenty-five feet; and they may be attributed, says Captain Beechey, to the aversion of the lithophytes to fresh water, and to the probable absence of the mineral matter of which they construct their habitations.*

Mr. Darwin, however, is of opinion, that mud at the bottom of river-courses is more influential than the freshness of the water in preventing the growth of the polypi, for the walls which inclose the openings

* *Voyage to the Pacific, &c., p. 194.*

are perpendicular, and do not slant off gradually, as would be the case, if the nature of the element presented the only obstacle to the increase of the coral-building animals.

When a breach has thus been made in the reef, it will be prevented from closing up by the efflux of the sea at low tides; for it is sufficient that a reef should rise a few feet above low-water mark to cause the waters to collect in the lagoon at high tide, and when the sea falls, to rush out at one or more points where the reef happens to be lowest or weakest. This event is strictly analogous to that witnessed in our estuaries, where a body of salt water accumulated during the flow issues with great velocity at the ebb of the tide, and scours out or keeps open a deep passage through the bar, which is almost always formed at the mouth of a river. At first there are probably many openings, but the growth of the coral tends to obstruct all those which do not serve as the principal channels of discharge; so that their number is gradually reduced to a few, and often finally to one.

Size of atolls and barrier reefs. — In regard to the dimensions of atolls, it was stated that some of the smallest observed by Beechey in the Pacific, were only a mile in diameter. If their external slope under water equals upon an average an angle of 45° , then would such an atoll at the depth of half a mile, or 2640 feet, have a diameter of two miles. Hence it would appear, that there must be a tendency in every atoll to grow smaller, except in those cases where oscillations of level enlarge the base on which the coral grows, by throwing down a talus of detrital matter all round the original cone of limestone. We have already shown, in the explanation of the diagram

(Fig. 98.), that if the rate of subsidence be accelerated at times, the dimensions of the encircling reef will be circumscribed. If, in spite of this tendency, we find so many lagoon islands of enormous size, it proves how uniform as well as slow has been the downward movement.

Bow Island is described by Captain Beechey as 70 miles in circumference, and 30 in its greatest diameter, and some of the Maldivas are said to be twice as large. The base of such atolls must be considerably larger, but we cannot calculate from the dimensions of the base, if known, what may have been the height of the island now changed into an atoll. In other words, we cannot estimate the thickness of the coral which has accumulated, for the inclination of the surface of an island from its highest peak to the shore varies greatly, and follows no fixed rule. Suppose, for example, we take the two largest of the Canaries, Fuertaventura, and the Peak of Teneriffe; the former is about 80 miles long by about 20 broad, and somewhat less than 2000 feet high, while Teneriffe is about 50 miles long, and its greatest breadth about 30 miles, its height being above 2 miles. If, therefore, both of these had been situated in the coral region of the Pacific, the smallest must have sunk about 11,000 feet, and the largest only 2000 feet, in order to be converted into atolls, in which case they might resemble in size some of the circular reefs now existing.

As the shore of an island or continent which is subsiding will recede from a coral reef at a slow or rapid rate, according as the surface of the land has a steep or gentle slope, we cannot measure the thickness of the coral by its distance from the coast; yet, as a general rule, those reefs which are farthest from the

land imply the greatest amount of subsidence. We learn from Flinders, that the barrier reef of north-eastern Australia is in some places seventy miles from the mainland, and it should seem that a calcareous formation is there in progress 1000 miles long from north to south, with a breadth varying from twenty to seventy miles. It may not, indeed, be continuous over this vast area, for doubtless innumerable islands have been submerged one after another between the reef and mainland, like some which still remain, as, for example, Murray's Islands, lat. $9^{\circ} 54' S.$ We are also told that some parts of the gulf inclosed within the barrier are 400 feet deep, so that the efficient corals cannot be growing there, and in other parts of it islands appear encircled by reefs.

Structure and Stratification. — It is curious to reflect that if the bottom of the equatorial seas where atolls abound, were upraised and laid dry, we should behold mountain-peaks and ridges composed fundamentally of volcanic, granitic, and other rocks, on which tabular masses of limestone would repose. Some of these calcareous cappings would be continuous over an area three miles, others above 300 miles in circumference, while their thickness might vary from 1000 to 10,000 feet, or more. They would consist principally of corals and shells, in some places entire, in others broken. In the lower regions of the same continent, and between the high table-lands or mountain-ridges, there would often be no contemporary deposits, or, where exceptions occurred to this rule, the calcareous strata would differ in their nature as much as in the species of fossils which they inclosed, from the tabular masses of coral. It has been observed that the softer corals, when they decompose in the lagoon, are

resolved into a white mud, which when dried is undistinguishable from common chalk.* This fine sediment must often be carried by the waves and currents to great distances, and sinking may envelope such zoophytes and brachiopodous mollusca, as inhabit deep water. Thus a recent cretaceous formation may now be in progress in many parts of the Pacific and Indian oceans.

Captain Beechey remarks, in a passage before cited, that the dead coral, which has been raised to the height of fifty feet and upwards in Henderson's Island, is more or less porous, and honey-combed at the surface, and hardening into a compact calcareous substance within. The same rock, he says, possesses the fracture of secondary limestone, and has a species of millepore dispersed through it.† The accounts of other observers attest, in like manner, the tendency of recent coral to become converted into solid limestone, for the percolating waters seem always ready to deposit carbonate of lime in the interstices. A certain degree of stratification will usually be imparted to coralline formations by the arrangement of particular species of zoophytes and testacea in particular beds. In other situations, the sand-pebbles and earthy particles brought into the sea by rivers, will cause divisions of a more marked character. If there has been an active volcano on the neighbouring land, showers of cinders or sheets of lava may interrupt suddenly the growth of one coral reef, and afterwards serve as a foundation for another. An example of this kind is seen in the Isle of France, where a bed of

* Lieut. Nelson, Geol. Trans., second series, vol. v

† Beechey, vol. i. p. 45.

coral, ten feet thick, intervenes between two currents of lava *; and in the West Indies, in the island of Dominica, Maclure observes, that “a bed of coral and madrepore limestone, with shells, lies horizontally on a bed of cinders, about 200 or 300 hundred feet above the level of the sea, at Rousseau, and is covered with cinders to a considerable height.” †

Lime, whence derived. — A modern writer has attempted to revive the theory of some of the earlier geologists, that all limestones have originated in organized substances. If we examine, he says, the quantity of limestone in the primary strata, it will be found to bear a much smaller proportion to the siliceous and argillaceous rocks than in the secondary; and this may have some connexion with the rarity of testaceous animals in the ancient ocean. He further infers, that in consequence of the operations of animals, “the quantity of calcareous earth deposited in the form of mud or stone is always increasing; and that, as the secondary series far exceeds the primary in this respect, so a third series may hereafter arise from the depths of the sea, which may exceed the last in the proportion of its calcareous strata.” ‡

If these propositions went no farther than to suggest that every particle of lime that now enters into the crust of the globe may possibly in its turn have been subservient to the purposes of life, by entering into the composition of organized bodies, I should not deem

* De la Bêche, Geol. Man., p. 142. Quoy and Gaimard, Ann. des Sci. Nat., tome vi.

† Observ. on Geology of the West Indian Islands, Journ. of Sci., &c. No. x. p. 318.

‡ MacCulloch's Syst. of Geol., vol. i. p. 219.

the speculation improbable ; but, when it is hinted that lime may be an animal product combined by the powers of vitality from some simple elements, I can discover no sufficient grounds for such an hypothesis, and many facts militate against it.

If a large pond be made, in almost any soil, and filled with rain water, it may usually become tenanted by testacea ; for carbonate of lime is almost universally diffused in small quantities. But if no calcareous matter be supplied by waters flowing from the surrounding high grounds, or by springs, no tufa or shell-marl are formed. The thin shells of one generation of mollusks decompose, so that their elements afford nutriment to the succeeding races ; and it is only where a stream enters a lake, which may introduce a fresh supply of calcareous matter, or where the lake is fed by springs, that shells accumulate and form marl.

All the lakes in Forfarshire which have produced deposits of shell-marl have been the sites of springs, which still evolve much carbonic acid, and a small quantity of carbonate of lime. But there is no marl in Loch Fithie, near Forfar, where there are *no springs*, although that lake is surrounded by these calcareous deposits, and although, in every other respect, the site is favourable to the accumulation of aquatic testacea.

We find those charæ which secrete the largest quantity of calcareous matter in their stems to abound near springs impregnated with carbonate of lime. We know that, if the common hen be deprived altogether of calcareous nutriment, the shells of her eggs will become of too slight a consistency to protect the contents ; and some birds eat chalk greedily during the breeding season.

If, on the other hand, we turn to the phenomena of

inorganic nature, we observe that, in volcanic countries, there is an enormous evolution of carbonic acid, either free, in a gaseous form, or mixed with water; and the springs of such districts are usually impregnated with carbonate of lime in great abundance. No one who has travelled in Tuscany, through the region of extinct volcanos and its confines, or who has seen the map constructed by Targioni (1827), to show the principal sites of mineral springs, can doubt, for a moment, that if this territory was submerged beneath the sea, it might supply materials for the most extensive coral reefs. The importance of these springs is not to be estimated by the magnitude of the rocks which they have thrown down on the slanting sides of hills, although of these alone large cities might be built, nor by a coating of travertin that covers the soil in some districts for miles in length. The greater part of the calcareous matter passes down in a state of solution to the sea, and in all countries the rivers which flow from chalk and other marly and calcareous rocks carry down vast quantities of lime into the ocean. Lime is also one of the component parts of augite and other volcanic and hypogene minerals, and when these decompose is set free, and may then find its way in a state of solution to the sea.

The lime, therefore, contained generally in sea-water, and secreted so plentifully by the testacea and corals of the Pacific, may have been derived either from springs rising up in the bed of the ocean, or from rivers fed by calcareous springs, or impregnated with lime derived from disintegrated rocks, both volcanic and hypogene. If this be admitted, the greater proportion of limestone in the more modern formations, as compared to the most ancient, will be explained, for

springs in general hold no argillaceous, and but a small quantity of siliceous matter in solution, but they are continually subtracting calcareous matter from the inferior rocks. The constant transfer, therefore, of carbonate of lime from the lower or older portions of the earth's crust to the surface, must cause at all periods, and throughout an indefinite succession of geological epochs, a preponderance of calcareous matter in the newer as contrasted with the older formations.

Concluding Remarks. — In the concluding chapters of the first book, I examined in detail a great variety of arguments which have been adduced to prove the distinctness of the state of the earth's crust at remote and recent epochs. Among other supposed proofs of this distinctness, the dearth of calcareous matter, in the ancient rocks above adverted to, might have been considered. But it would have been endless to enumerate all the objections urged against those geologists who represent the course of nature at the earliest periods as resembling in all essential circumstances the state of things now established. We have seen that, in opposition to this doctrine, a strong desire has been manifested to discover in the ancient rocks the signs of an epoch when the planet was uninhabited, and when its surface was in a chaotic condition and uninhabitable. The opposite opinion, indeed, that the oldest of the rocks now visible may be the last monuments of an antecedent era in which living beings may already have peopled the land and water, has been declared to be equivalent to the assumption that there never was a beginning to the present order of things.

With equal justice might an astronomer be accused of asserting that the works of creation extended

throughout *infinite* space, because he refuses to take for granted that the remotest stars now seen in the heavens, are on the utmost verge of the material universe. Every improvement of the telescope has brought thousands of new worlds into view; and it would, therefore, be rash and unphilosophical to imagine that we already survey the whole extent of the vast scheme, or that it will ever be brought within the sphere of human observation.

But no argument can be drawn from such premises in favour of the infinity of the space that has been filled with worlds; and if the material universe has any limits, it then follows, that it must occupy a minute and infinitesimal point in infinite space.

So if, in tracing back the earth's history, we arrive at the monuments of events which may have happened millions of ages before our times, and if we still find no decided evidence of a commencement, yet the arguments from analogy in support of the probability of a beginning remain unshaken; and if the past duration of the earth be finite, then the aggregate of geological epochs, however numerous, must constitute a mere moment of the past, a mere infinitesimal portion of eternity.

It has been argued, that, as the different states of the earth's surface, and the different species by which it has been inhabited, have all had their origin, and many of them their termination, so the entire series may have commenced at a certain period. It has also been urged, that, as we admit the creation of man to have occurred at a comparatively modern epoch — as we concede the astonishing fact of the first introduction of a moral and intellectual being — so also we may conceive the first creation of the planet itself.

I am far from denying the weight of this reasoning from analogy; but, although it may strengthen our conviction, that the present system of change has not gone on from eternity, it cannot warrant us in presuming that we shall be permitted to behold the signs of the earth's origin, or the evidences of the first introduction into it of organic beings. We aspire in vain to assign limits to the works of creation in *space*, whether we examine the starry heavens, or that world of minute animalcules which is revealed to us by the microscope. We are prepared, therefore, to find that in *time* also the confines of the universe lie beyond the reach of mortal ken. But in whatever direction we pursue our researches, whether in time or space, we discover every where the clear proofs of a Creative Intelligence, and of His foresight, wisdom, and power.

As geologists, we learn that it is not only the present condition of the globe which has been suited to the accommodation of myriads of living creatures, but that many former states also have been adapted to the organization and habits of prior races of beings. The disposition of the seas, continents, and islands, and the climates, have varied; the species likewise have been changed; and yet they have all been so modelled, on types analogous to those of existing plants and animals, as to indicate, throughout, a perfect harmony of design and unity of purpose. To assume that the evidence of the beginning or end of so vast a scheme lies within the reach of our philosophical inquiries, or even of our speculations, appears to be inconsistent with a just estimate of the relations which subsist between the finite powers of man and the attributes of an Infinite and Eternal Being.

GLOSSARY

OF GEOLOGICAL AND OTHER SCIENTIFIC TERMS USED
IN THIS WORK.

ACEPHALOUS. The Acephala are that division of molluscous animals which, like the oyster and scallop, are without heads. The class Acephala of Cuvier comprehends many genera of animals with bivale shells, and a few which are devoid of shells. *Etym.*, *a*, *a*, without, and *κεφαλη*, *cephale*, the head.

ACIDULOUS. Slightly acid.

ADIPOCIRE. A substance apparently intermediate between fat and wax, into which dead animal matter is converted when buried in the earth, and in a certain stage of decomposition. *Etym.*, *adeps*, fat, and *cera*, wax.

ALBITE. See "Felspar."

ALEMBIC. An apparatus for distilling.

ALGÆ. An order or division of the cryptogamic class of plants. The whole of the sea-weeds are comprehended under this division, and the application of the term in this work is to marine plants. *Etym.*, *alga*, sea-weed.

ALLUVIAL. The adjective of alluvium, which see.

ALLUVION. Synonymous with alluvium, which see.

ALLUVIUM. Earth, sand, gravel, stones, and other transported matter which has been washed away and thrown down by rivers, floods, or other causes, upon land not *permanently* submerged beneath the waters of lakes or seas. *Etym.*, *alluo*, to wash upon, or *alluvio*, an inundation.

ALUM-STONE, ALUMEN, ALUMINOUS. Alum is the base of pure clay, and strata of clay are often met with containing much iron-pyrites. When the latter substance decomposes, sulphuric acid is produced, which unites with the aluminous earth

of the clay to form sulphate of alumine, or common alum. Where manufactories are established for obtaining the alum, the indurated beds of clay employed are called Alum-stone.

AMMONITE. An extinct and very numerous genus of the order of molluscous animals called Cephalopoda, allied to the modern genus *Nautilus*, which inhabited a chambered shell, curved like a coiled snake. Species of it are found in all geological periods of the secondary strata; but they have not been seen in the tertiary beds. They are named from their resemblance to the horns on the statues of Jupiter Ammon.

AMORPHOUS. Bodies devoid of regular form. *Etym.*, *a, a*, without, and *μορφη*, *morphe*, form.

AMYGDALOID. One of the forms of the Trap-rocks, in which agates and simple minerals appear to be scattered like almonds in a cake. *Etym.*, *αμυγδαλα*, *amygdala*, an almond.

ANALCIME. A simple mineral of the Zeolite family, also called Cubizite, of frequent occurrence in the Trap-rocks.

ANALOGUE. A body that resembles or corresponds with another body. A recent shell of the same species as a fossil shell is the analogue of the latter.

ANOPLOTHERIUM. A fossil extinct quadruped belonging to the order Pachydermata, resembling a pig. It has received its name because the animal must have been singularly wanting in means of defence, from the form of its teeth and the absence of claws, hoofs, and horns. *Etym.*, *ἀνοπλός*, *anoplos*, unarmed, and *θηρίον*, *therion*, a wild beast.

ANTAGONIST POWERS. Two powers in nature, the action of the one counteracting that of the other, by which a kind of equilibrium or balance is maintained, and the destructive effect prevented that would be produced by one operating without a check.

ANTENNAE. The articulated horns with which the heads of insects are invariably furnished.

ANTHRACITE. A shining substance like black-lead; a species of mineral charcoal. *Etym.*, *ἀνθράξ*, *anthrax*, coal.

ANTHRACOTHERIUM. A name given to an extinct quadruped, supposed to belong to the Pachydermata, the bones of which were first found in lignite and coal of the tertiary strata. *Etym.*, *ἀνθράξ*, *anthrax*, coal, and *θηρίον*, *therion*, wild beast.

ANTHROPOMORPHOUS. Having a form resembling the human.

Etym., ανθρωπος, *anthropos*, a man, and μορφη, *morphe*, form..

ANTISEPTIC. Substances which prevent corruption in animal and vegetable matter, as common salt does, are said to be anti-septic. *Etym.*, αντι, *against*, and σηπω, *sepo*, to putrefy.

ARENACEOUS. Sandy. *Etym.*, *arena*, sand.

ARGILLACEOUS. Clayey, composed of clay. *Etym.*, *argilla*, clay.

ARRAGONITE. A simple mineral, a variety of carbonate of lime, so called from having been first found in Arragon, in Spain.

ATOLLS. Coral islands of an annular form, or consisting of a circular strip or ring of coral surrounding a central lagoon.

AUGITE. A simple mineral of a dark green, or black colour, which forms a constituent part of many varieties of volcanic rocks. Name applied by Pliny to a particular mineral, from the Greek αυγη, *auge*, lustre.

avalanches. Masses of snow which, being detached from great heights in the Alps, acquire enormous bulk by fresh accumulations as they descend; and when they fall into the valleys below often cause great destruction. They are also called *lavanges*, and *lavanches*, in the dialects of Switzerland.

BASALT. One of the most common varieties of the Trap-rocks. It is a dark green or black stone, composed of augite and felspar, very compact in texture, and of considerable hardness, often found in regular pillars of three or more sides called basaltic columns. Remarkable examples of this kind are seen at the Giant's Causeway, in Ireland, and at Fingal's Cave, in Staffa, one of the Hebrides. The term is used by Pliny, and is said to come from *basal*, an Æthiopian word signifying iron. The rock often contains much iron.

“**BASIN**” of Paris, “**BASIN**” of London. Deposits lying in a hollow or trough, formed of older rocks; sometimes used in geology almost synonymously with “formations,” to express the deposits lying in a certain cavity or depression in older rocks.

BELEMNITE. An extinct genus of the order of molluscous animals called Cephalopoda, having a long, straight, and chambered conical shell. *Etym.*, βελεμνον *belemnion*, a dart.

BITUMEN. Mineral pitch, of which the tar-like substance which

is often seen to ooze out of the Newcastle coal when on the fire, and which makes it cake, is a good example. *Etym.*, *bitumen*, pitch.

BITUMINOUS SHALE. An argillaceous shale, much impregnated with bitumen, which is very common in the Coal Measures.

BLENDE. A metallic ore, a compound of the metal zinc with sulphur. It is often found in brown shining crystals; hence its name among the German miners, from the word *blenden*, to dazzle.

BLUFFS. High banks presenting a precipitous front to the sea or a river. A term used in the United States of North America.

BOTRYOIDAL. Resembling a bunch of grapes. *Etym.*, *batrys*, a bunch of grapes, and *eidos*, *eides*, form.

BOULDERS. A provincial term for large rounded blocks of stone lying on the surface of the ground, or sometimes imbedded in loose soil, different in composition from the rocks in their vicinity, and which have been therefore transported from a distance.

BRECCIA. A rock composed of angular fragments connected together by lime or other mineral substance. An Italian term.

CALC SINTER. A German name for the deposits from springs holding carbonate of lime in solution — petrifying springs. *Etym.*, *kalk*, lime *sintern*, to drop.

CALCAIRE GROSSEILLE. An extensive stratum, or rather series of strata, found in the Paris Basin, belonging to the Eocene tertiary period. *Etym.*, *calcaire*, limestone, and *grossier*, coarse.

CALCAREOUS ROCK. Limestone. *Etym.*, *calx*, lime.

CALCAREOUS SPAR. Crystallized carbonate of lime.

CALCEDONY. A siliceous simple mineral, uncry stallized. Agates are partly composed of calcedony.

CARBON. An undecomposed inflammable substance, one of the simple elementary bodies. Charcoal is almost entirely composed of it. *Etym.*, *carbo*, coal.

CARBONATE OF LIME. Lime combines with great avidity with carbonic acid, a gaseous acid only obtained fluid when united with water,— and all combinations of it with other substances.

are called *Carbonates*. All limestones are carbonates of lime, and quick lime is obtained by driving off the carbonic acid by heat.

CARBONATED SPRINGS. Springs of water, containing carbonic acid gas. They are very common, especially in volcanic countries; and sometimes contain so much gas, that if a little sugar be thrown into the water it effervesces like soda-water.

CARBONIC ACID GAS. A natural gas which often issues from the ground, especially in volcanic countries. *Etym.*, *carbo*, coal; because the gas is obtained by the slow burning of charcoal.

CARBONIFEROUS. A term usually applied, in a technical sense, to an ancient group of secondary strata; but any bed containing coal may be said to be carboniferous. *Etym.*, *carbo*, coal, and *fero*, to bear.

CATACLYSM. A deluge. *Etym.*, κατακλυσμός, *catacluzo*, to deluge.

CEPHALOPODA. A class of molluscous animals, having their organs of motion arranged round their head. *Etym.*, κεφαλή, *cephale*, head, and ποδά, *poda*, feet.

CETACEA. An order of vertebrated mammiferous animals inhabiting the sea. The whale, dolphin, and narwal are examples. *Etym.*, *cete*, whale.

CHALK. A white earthy limestone, the uppermost of the secondary series of strata.

CHERT. A siliceous mineral, nearly allied to calcedony and flint, but less homogeneous and simple in texture. A gradual passage from chert to limestone is not uncommon.

CHLORITIC SAND. Sand coloured green by an admixture of the simple mineral chlorite. *Etym.*, χλωρός, *chloros*, green.

CLEAVAGE. Certain rocks, usually called Slate-rocks, may be cleaved into an indefinite number of thin laminæ which are parallel to each other, but which are generally not parallel to the planes of the true strata or layers of deposition. The planes of cleavage, therefore, are distinguishable from those of stratification.

CLINKSTONE, called also phonolite, a felspathic rock of the trap family, usually fissile. It is sonorous when struck with a hammer, whence its name.

COAL FORMATION. This term is generally understood to mean the same as the Coal Measures, or Carboniferous group.

COLEOPTERA. An order of insects (Beetles) which have four wings, the upper pair being crustaceous and forming a shield.
Etym., κολεός, *coleos*, a sheath, and πτερον, *pteron*, a wing.

CONFORMABLE. When the planes of one set of strata are generally parallel to those of another set which are in contact they are said to be conformable. Thus the set *a, b*, Fig. 99.

Fig. 99.



rest conformably on the inferior set *c, d*; but *c, d* rest unconformably on *E*.

CONGENERS. Species which belong to the same genus.

CONGLOMERATE, or PUDDINGSTONE. Rounded water-worn fragments of rock or pebbles, cemented together by another mineral substance, which may be of a siliceous, calcareous, or argillaceous nature. *Etym.*, *con*, together, *glomero*, to heap.

CONIFERÆ. An order of plants which, like the fir and pine, bear cones or tops in which the seeds are contained. *Etym.*, *conus*, cone, and *fero*, to bear.

COSMOGONY, COSMOLOGY. Words synonymous in meaning, applied to speculations respecting the first origin or mode of creation of the earth. *Etym.*, κοσμος, *kosmos*, the world, and γονη, *gonee*, generation, or λογος, *logos*, discourse.

CRAIG. A provincial name in Norfolk and Suffolk for certain tertiary deposits usually composed of sand with shells, belonging to the Older Pliocene period.

CRATER. The circular cavity at the summit of a volcano, from which the volcanic matter is ejected. *Etym.*, *crater*, a great cup or bowl.

CRETACEOUS. Belonging to chalk. *Etym.*, *creta*, chalk.

CROP OUT. A miner's or mineral surveyor's term, to express the rising up or exposure at the surface of a stratum or series of strata.

CRUST OF THE EARTH. See "Earth's crust."

CRUSTACEA. Animals having a shelly coating or crust which

they cast periodically. Crabs, shrimps, and lobsters, are examples.

CRYPTOGAMIC. A name applied to a class of plants, such as ferns, mosses, sea-weeds, and fungi, in which the fructification or organs of reproduction are concealed. *Etym.*, κρυπτός, *kryptos*, concealed, and γάμος, *gamos*, marriage.

CRYSTALS. Simple minerals are frequently found in regular forms, with facets like the drops of cut glass of chandeliers.

Quartz being often met with in rocks in such forms, and beautifully transparent like ice, was called *rock-crystal*, κρυσταλλος, *crystallos*, being Greek for ice. Hence the regular *forms* of other minerals are called crystals, whether they be clear or opake.

CRYSTALLIZED. A mineral which is found in regular forms or crystals is said to be crystallized.

CRYSTALLINE. The internal texture which regular crystals exhibit when broken, or a confused assemblage of ill-defined crystals. Loaf-sugar and statuary-marble have a *crystalline* texture. Sugar-candy and calcareous spar are crystallized.

CUPRIFEROUS. Copper-bearing. *Etym.*, *cuprum*, copper, and *fero*, to bear.

CYCADEÆ. An order of plants which are natives of warm climates, mostly tropical, although some are found at the Cape of Good Hope. They have a short stem, surmounted by a peculiar foliage, termed pinnated fronds by botanists, which spreads in a circle. The term is derived from κυκας, *cycas*, a name applied by the ancient Greek naturalist Theophrastus to a palm.

CYPERACEÆ. A tribe of plants answering to the English sedges; they are distinguished from grasses by their stems being solid, and generally triangular, instead of being hollow and round. Together with *gramineæ* they constitute what writers on botanical geography often call *glumaceæ*.

DEBACLE. A great rush of waters, which, breaking down all opposing barriers, carries forward the broken fragments of rocks, and spreads them in its course. *Etym.*, *débâcler*, French, to unbar, to break up as a river does at the cessation of a long-continued frost.

DELTA. When a great river, before it enters the sea, divides into

separate streams, they often diverge and form two sides of a triangle, the sea being the base. The land included by the three lines, and which is invariably alluvial, was first called, in the case of the Nile, a delta, from its resemblance to the letter of the Greek alphabet which goes by that name Δ. Geologists apply the term to alluvial land formed by a river at its mouth, without reference to its precise shape.

DENUDATION. The carrying away by the action of running water of a portion of the solid materials of the land, by which inferior rocks are laid bare. *Etym.*, *denudo*, to lay bare.

DEOXIDIZED, DEOXIDATED. Deprived of oxygen. Disunited from oxygen.

DESICCATION. The act of drying up. *Etym.*, *desiccō*, to dry up.

DETITUS. Matter worn or rubbed off from rocks. *Etym.*, *de*, from, and *tereo*, to rub.

DICOTYLEDONOUS. A grand division of the vegetable kingdom, founded on the plant having two cotyledons, or seed-lobes. *Etym.*, *δις*, *dis*, double, and *κοτυληδων*, cotyledon.

DIKES. When a mass of the unstratified or igneous rocks, such as granite, trap, and lava, appears as if injected into a rent in the stratified rocks, cutting across the strata, it forms a dike. They are sometimes seen running along the ground, and projecting, like a wall, from the softer strata on both sides of them having wasted away; whence they were first called in the north of England and in Scotland *dikes*, a provincial name for wall. It is not easy to draw the line between dikes and veins. The former are generally of larger dimensions, and have their sides parallel for considerable distances; while veins have generally many ramifications, and these often thin away into slender threads.

DILUVIUM. Those accumulations of gravel and loose materials which, by some geologists, are said to have been produced by the action of a diluvian wave or deluge sweeping over the surface of the earth. *Etym.*, *diluvium*, deluge.

DIP. When a stratum does not lie horizontally, but is inclined, it is said to *dip* towards some point of the compass, and the angle it makes with the horizon is called the angle of dip or inclination.

DIPTERA. An order of insects, comprising those which have

only two wings. *Etym.*, δις δις, double, and πτερον, pteron, wing.

DOLERITE. One of the varieties of the Trap-rocks, composed of augite and felspar.

DOLomite. A crystalline limestone, containing magnesia as a constituent part. Named after the French geologist Dolomieu.

DUNES. Low hills of blown sand that skirt the shores of Holland, England, Spain, and other countries.

EARTH'S CRUST. Such superficial parts of our planet as are accessible to human observation.

ECPYROSIS. A Greek term for a destruction by fire.

ELYTRA. The wing-sheaths, or upper crustaceous membranes, which form the superior wings in the tribe of beetles. They cover the body, and protect the true membranous wing. *Etym.*, ελυτρον, elytron, a sheath.

ENTOMOSTRACA. Cuvier's second section of Crustacea; so called from their relationship to insects. *Etym.*, εντόμα, entoma, insects.

Eocene. A name given to the lowest division of the tertiary strata, containing an extremely small per-cent of living species amongst its fossil shells, which indicate the first commencement or dawn of the existing state of the animate creation. *Etym.*, ηως, eos, aurora or the dawn, and καινος, kainos, recent.

ESCARPMENT. The abrupt face of a ridge of high land. *Etym.*, escarper, French, to cut steep.

ESTUARIES. Inlets of the land, which are entered both by rivers and the tides of the sea. Thus we have the estuaries of the Thames, Severn, Tay, &c. *Etym.*, aestus, the tide.

EXPERIMENTUM CRUCIS. A decisive experiment, so called, because, like a cross or direction post, it directs men to true knowledge; or, as some explain it, because it is a kind of torture whereby the nature of the thing is extorted, as it were, by violence.

EXUVIAE. Properly speaking, the transient parts of certain animals, which they put off or lay down to assume new ones, as serpents and caterpillars shift their skins; but in geology it refers not only to the cast-off coverings of animals, but to

fossil shells and other remains which animals have left in the strata of the earth. *Etym.*, *exuere*, to put off or divest.

FALUNA. A French provincial name for some tertiary strata abounding in shells in Touraine, which resemble in lithological characters the "Crag" of Norfolk and Suffolk.

FAULT, in the language of miners, is the sudden interruption of the continuity of strata in the same plane, accompanied by a crack or fissure, varying in width from a mere line to several feet, which is generally filled with broken stone, clay, &c.

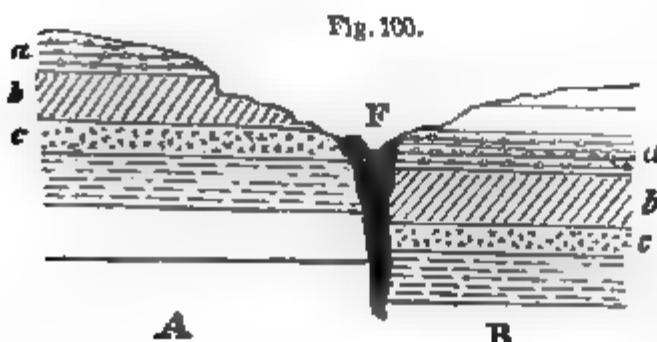


Fig. 100.

The strata *a*, *b*, *c*, &c., must at one time have been continuous; but a fracture having taken place at the fault *F*, either by the

upheaving of the portion *A*, or the sinking of the portion *B*, the strata were so displaced that the bed *a* in *B* is many feet lower than the same bed *a* in the portion *A*.

FAUNA. The various kinds of animals peculiar to a country constitute its FAUNA, as the various kinds of plants constitute its FLORA. The term is derived from the *Fauni*, or rural deities, in Roman Mythology.

FELSPAR. A simple mineral, which, next to quartz, constitutes the chief material of rocks. The white angular portions in granite are felspar. This mineral always contains some alkali in its composition. In common felspar the alkali is potash; in another variety, called Albite or Cleavlandite, it is soda. Glassy felspar is a term applied when the crystals have a considerable degree of transparency. Compact felspar is a name of more vague signification. The substance so called appears to contain both potash and soda.

FELSPATHIC. Of or belonging to felspar.

FERRUGINOUS. Any thing containing iron. *Etym.*, *ferrum*, iron.

FLOORS ROCKS. A German term applied to the secondary strata.

by the geologists of that country, because these rocks were supposed to occur most frequently in flat horizontal beds.
Etym. *flötz*, a layer or stratum.

FLORA. The various kinds of trees and plants found in any country constitute the **FLORA** of that country in the language of botanists.

FLUVIALTILE. Belonging to a river. *Etym.*, *fluvius*, a river.

FORAMINIFERA. A name given by D'Orbigny to a family of microscopic shells. Their different chambers are united by a small perforation or *foramen*. Recent observation has shown that some at least are not cephalopoda, as D'Orbigny supposed.

FORMATION. A group, whether of alluvial deposits, sedimentary strata, or igneous rocks, referred to a common origin or period.

Fossil. All minerals were once called fossils, but geologists now use the word only to express the remains of animals and plants found buried in the earth. *Etym.*, *fossilis*, any thing that may be dug out of the earth.

Fossiliferous. Containing organic remains.

GALENA. A metallic ore, a compound of lead and sulphur. It has often the appearance of highly polished lead. *Etym.*, *γαλεω*, *galeo*, to shine.

GARNET. A simple mineral, generally of a deep red colour, crystallized; most commonly met with in mica slate, but also in granite and other igneous rocks.

GASTEROPODS. A division of the Testacea, in which, as in the limpet, the foot is attached to the body. *Etym.*, *γαστηρ*, *gaster*, belly, and *ποδα*, *poda*, feet.

GAULT. A provincial name in the east of England for a series of beds of clay and marl, the geological position of which is between the Upper and Lower Green-sand.

GAVIAL. A kind of crocodile found in India.

GEM, or **GEMMULE**, from the Latin *gemma*, a bud. The term, applied to zoophytes, means a young animal not confined within an envelope or egg.

GEOLOGY, GEOGNOSY. Both mean the same thing; but with an unnecessary degree of refinement in terms, it has been proposed to call our description of the structure of the earth

geognosy (*Etym.*, γεα, *gea*, earth, and γνωσκω *ginosko*, to know), and our theoretical speculations as to its formation
geology (*Etym.*, γεα, and λογος, *logos*, a discourse).

GLACIER. Vast accumulations of ice and hardened snow in the Alps and other lofty mountains. *Etym.*, *glace*, French for ice.

GLACIS. A term borrowed from the language of fortification, where it means an easy insensible slope or declivity, less steep than a *talus*, which see.

GNEISS. A stratified primary rock, composed of the same materials as granite, but having usually a larger proportion of mica and a laminated texture. The word is a German miner's term.

GRAMINEAE. The order of plants to which grasses belong.
Etym., *gramen*, grass.

GRANITE. An unstratified or igneous rock, generally found inferior to or associated with the oldest of the stratified rocks, and sometimes penetrating them in the form of dikes and veins. It is usually composed of three simple minerals, felspar, quartz, and mica, and derives its name from having a coarse *granular* structure; *granum*, Latin for grain. Westminster, Waterloo, and London bridges, and the paving-stones in the carriage-way of the London streets, afford good examples of the most common varieties of granite.

GREENSAND. Beds of sand, sandstone, limestone, belonging to the Cretaceous Period. The name is given to these beds because they often, but not always, contain an abundance of green earth or chlorite scattered through the substance of the sandstone, limestone, &c.

GREENSTONE. A variety of trap, composed of hornblende and felspar.

GREYWACKE. *Grauwacke*, a German name, generally adopted by geologists for some of the most ancient fossiliferous strata. The rock is very often of a grey colour; hence the name, *grau*, being German for grey, and *wacke*, being a provincial miner's term.

GRIT. A provincial name for a coarse-grained sandstone.

GYPSUM. A mineral composed of lime and sulphuric acid, hence called also *sulphate of lime*. Plaster and stucco are obtained by exposing gypsum to a strong heat. It is found so abun-

dantly near Paris that plaster of Paris is a common term in this country for the white powder of which casts are made. The term is used by Pliny for a stone used for the same purposes by the ancients. The derivation is unknown.

GYPSEOUS, of or belonging to gypsum.

GYROGONITES. Bodies found in freshwater deposits, originally supposed to be microscopic shells, but subsequently discovered to be the seed-vessel of freshwater plants of the genus *Chara*. See Vol. III. p. 350. *Etym.*, γυπος, *gyros*, curved, and γονος, *gonos*, seed, on account of their external structure.

HEMIPTERA. An order of insects, so called from a peculiarity in their wings, the superior being coriaceous at the base, and membranous at the apex, ἡμίσυ, *hemis*, half, and πτερον, *pteron*, wing.

HORNBLENDE. A simple mineral of a dark green or black colour, which enters largely into the composition of several varieties of the Trap-rocks.

HORNSTONE. A siliceous mineral substance, sometimes approaching nearly to flint, or common quartz. It has a conchoidal fracture, and is infusible, which distinguishes it from compact felspar.

HUMERUS. The bone of the upper arm.

HYDROPHYTES. Plants which grow in water. *Etym.*, ὕδωρ, *hydor*, water, and φυτόν, *phyton*, plant.

HYPogene Rocks. Those rocks which are *nether-formed*, or which have not assumed their present form and structure at the surface, such as granite, gneiss, &c. This term, which includes both the plutonic and metamorphic rocks, is substituted for *primary*, because some members of both these classes, such as granite and gneiss, are posterior to many secondary or fossiliferous rocks. *Etym.*, ὑπό, *hypo*, under, and γίνομαι, *ginomai*, to be formed or produced.

ICEBERG. Great masses of ice, often the size of hills, which float in the polar and adjacent seas. *Etym.*, ice, and *berg*, German for hill.

ICHTHYOSAURUS. A gigantic fossil marine reptile, intermediate between a crocodile and a fish. *Etym.*, ἰχθύς, *ichthus*, a fish, and σαῦρος, *saura*, a lizard.

IGNEOUS ROCKS. All rocks, such as lava, trap, and granite, known or supposed to have been melted by volcanic heat.

INCANDESCENT. White hot—having a more intense degree of heat than red heat.

INDUCTION. A consequence, inference, or general principle drawn from a number of particular facts or phenomena. The inductive philosophy, says Mr. Whewell, has been rightly described as a science which ascends from particular facts to general principles, and then descends again from these general principles to particular applications.

INFUSORY ANIMALCULES. Minute living creatures found in many *infusions*; and the term *infusori* has been given to all such animalcules, whether found in infusions or in stagnant water, vinegar, &c.

INSPISSATED. Thickened. *Etym.*, *spissus*, thick.

INVERTEBRATED ANIMALS. Animals which are not furnished with a back-bone. For a further explanation, see “Vertebrated Animals.”

IOTHERMAL. Such zones or divisions of the land, ocean, or atmosphere, which have an equal degree of mean annual warmth, are said to be isothermal, from *isos*, *isos*, equal, and *θερμη*, *therme*, heat.

JOINTS. Fissures or lines of parting in rocks, often at right angles to the planes of stratification. The partings which divide columnar basalt into prisms are joints.

JURA LIMESTONE. The limestones belonging to the Oolitic Group constitute the chief part of the mountains of the Jura, between France and Switzerland; and hence the geologists of the Continent have given the name to the group.

KRUPER, a German name for a member of the Upper New Red Sandstone.

KIMMERIDGE CLAY. A thick bed of clay, constituting a member of the Oolite Group. So called, because it is found well developed at Kimmeridge in the isle of Purbeck, Dorsetshire.

LACUSTRINE. Belonging to a lake. *Etym.*, *lacus*, a lake.

LAMANTINE. A living species of the herbivorous Cetacea or

whale tribe, which inhabits the mouths of rivers on the coast of Africa and South America : the sea-cow.

LAMELLIFEROUS. Having a structure consisting of thin plates or leaves like paper. *Etym.*, *lamella*, the diminutive of *lamina*, plate, and *fero*, to bear.

LAMINÆ. Latin for plates ; used in geology for the smaller layers of which a stratum is frequently composed.

LANDSLIP. A portion of land that has slid down in consequence of disturbance by an earthquake, or from being undermined by water washing away the lower beds which supported it.

LAPIDIFICATION — Lapidifying process. Conversion into stone.
Etym., *lapis*, stone, and *fio*, to make.

LAPILLI. Small volcanic cinders. *Lapillus*, a little stone.

LAVA. The stone which flows in a melted state from a volcano.

LEPIDODENDRON, a genus of fossil plants of the Coal Measures, intermediate in character between the Lycopodiums and coniferous plants.

LEUCITE. A simple mineral found in volcanic rocks, crystallized, and of a white colour. *Etym.*, *λευκος leucos*, white.

LIAS. A provincial name for an argillaceous limestone, characterized together with its associated beds by peculiar fossils, and forming a particular group of strata, interposed between the Oolite and New Red Sandstone.

LIGNIPERDIOUS. A term applied to insects which destroy wood.
Etym., *lignum*, wood, and *perdo*, to destroy.

LIGNITE. Wood converted into a kind of coal. *Etym.*, *lignum*, wood.

LITHODOMI. Molluscous animals which form holes in solid rocks in which they lodge themselves. The holes are not perforated mechanically, but the rock appears to be dissolved.
Etym., *λιθος lithos*, stone, and *δεμω demo*, to build.

LITHOGENOUS POLYPS. Animals which form coral.

LITHOGRAPHIC STONE. A slaty compact limestone, of a yellowish colour and fine grain, used in lithography, which is the art of drawing upon and printing from stone. *Etym.*, *λιθος lithos*, stone, and *γραφω grapho*, to write.

LITHOIDAL. Having a stony structure.

LITHOLOGICAL. A term expressing the stony structure or charac-

ter of a mineral mass. We speak of the lithological character of a stratum as distinguished from its zoological character.

Etym., λίθος, *lithos*, stone, and λόγος, *logos*, discourse.

LITHOPHAGI. Molluscous animals which form holes in solid stones.

See "Lithodomi." *Etym.*, λίθος, *lithos*, stone, and φαγεῖν, *phagein*, to eat.

LITHOPHYTES. The animals which form Stone-coral.

LITTORAL. Belonging to the shore. *Etym.*, *littus*, the shore.

LOAM. A mixture of sand and clay.

LEPHIODON. A genus of extinct quadrupeds, allied to the tapir, named from eminences on the teeth.

Lycopodiaceæ. Plants of an inferior degree of organization to Coniferæ, some of which they very much resemble in foliage, but all recent species are infinitely smaller. Many of the fossil species are as gigantic as recent Coniferæ. Their mode of reproduction is analogous to that of ferns. In English they are called club-mosses, generally found in mountainous heaths in the north of England.

LYDIAN STONE. Flinty slate; a kind of quartz or flint, allied to Hornstone, but of a greyish black colour.

MACIGNO. In Italy this term has been applied to a siliceous sandstone sometimes containing calcareous grains, mica, &c.

MADREPORE. A genus of corals, but generally applied to all the corals distinguished by superficial star-shaped cavities. There are several fossil species.

MAGNESIAN LIMESTONE. An extensive series of beds, the geological position of which is immediately above the Coal Measures; so called, because the limestone, the principal member of the series, contains much of the earth magnesia as a constituent part.

MAMMIFEROUS. Mammifers. Animals which give suck to their young. To this class all the warm-blooded quadrupeds, and the Cetacea, or whales, belong. *Etym.*, *mamma*, a breast, *fero*, to bear.

MAMMILLARY. A surface which is studded over with rounded projections. *Etym.* *mammilla*, a little breast or pap.

MAMMOTH. An extinct species of the elephant (*E. primigenius*), of which the fossil bones are frequently met with in various

COUNTRIES. The name is of Tartar origin, and is used in Siberia for animals that burrow under ground.

MANATI. One of the Cetacea, the sea-cow, or lamantine (*Trichechus manatus*, Lin.)

MARL. A mixture of clay and lime; usually soft, but sometimes hard, in which case it is called indurated marl.

MARSUPIAL ANIMALS. A tribe of quadrupeds having a sack or pouch under the belly, in which they carry their young. The kangaroo is a well-known example. *Etym.*, *marsupium*, a purse.

MASTODON. A genus of fossil extinct quadrupeds allied to the elephants; so called from the form of the hind teeth or grinders, which have their surface covered with conical mamillary crests. *Etym.*, *μαυρος*, *mastos*, pap, and *οδων*, *odon*, tooth.

MATRIX. If a simple mineral or shell, in place of being detached, be still fixed in a portion of rock, it is said to be in its matrix.
Matrix, womb.

MECHANICAL ORIGIN, ROCKS OF. Rocks composed of sand, pebbles, or fragments, are so called, to distinguish them from those of a uniform crystalline texture, which are of chemical origin.

MEDUSA. A genus of marine radiated animals, without shells; so called, because their organs of motion spread out like the snaky hair of the fabulous Medusa.

MEGALOSAURUS. A fossil gigantic amphibious animal of the saurian or lizard and crocodile tribe. *Etym.*, *μεγαλη*, *megale*, great, and *σαυρα*, *saura*, lizard.

MEGATHERIUM. A fossil extinct quadruped, resembling a gigantic sloth. *Etym.*, *μεγα*, *mega*, great, and *θηρια*, *therion*, wild beast.

MELASTOMA. A genus of MELASTOMACEA, an order of exotic plants of the evergreen tree, and shrubby kinds. *Etym.*, *μελας*, *melas*, black, and *στομα*, *stoma*, mouth; because the fruit of one of the species stains the lips.

MESOTYPE. A simple mineral, white, and needle-shaped, one of the Zeolite family, frequently met with in the Trap-rocks.

METAMORPHIC ROCKS. A stratified division of hypogene rocks, highly crystalline, such as gneiss and mica-schist, and so

named because they have been *altered* by plutonic action.

Etym., μετα, *meta*, trans, and μορφη, *morphe*, form.

MICA. A simple mineral, having a shining silvery surface, and capable of being split into very thin elastic leaves or scales. It is often called *talc* in common life ; but mineralogists apply the term talc to a different mineral. The brilliant scales in granite are mica. *Etym.*, *mico*, to shine.

MICA-SLATE, **MICA SCHIST**, **MICACEOUS SCHISTUS**. One of the metamorphic or crystalline stratified rocks, of the hypogene class, which is characterized by being composed of a large proportion of mica united with quartz.

MIOCENE. A division of tertiary strata intervening between the Eocene and Pliocene formations ; so called, because a minority of its fossil shells are referable to living species. *Etym.*, μειων, *meion*, less, and καινος, *kainos*, recent.

MOLASSE. A provincial name for a soft green sandstone, associated with marl and conglomerates, belonging to the Miocene Tertiary Period, extensively developed in the lower country of Switzerland. *Etym.*, French, *molle*, soft.

MOLLUSCA, **MOLLUSCOUS ANIMALS**. Animals, such as shell-fish, which, being devoid of bones, have soft bodies. *Etym.*, *mollis*, soft.

MONAD. The smallest of visible animalcules, spoken of by Buffon and his followers as constituting the elementary molecules of organic beings.

MONITOR. An animal of the saurian or lizard tribe, species of which are found in both the fossil and recent state.

MONOCOTYLEDONOUS. A grand division of the vegetable kingdom (including palms, grasses, *Lilaceæ*, &c.), founded on the plant having only one *cotyledon*, or seed-lobe. *Etym.*, μονος, *monos*, single.

MORAINE, a Swiss term for the débris of rocks brought into valleys by glaciers. See Vol. I. p. 377.

MOSCHUS. A quadruped resembling the chamois or mountain goat, from which the perfume musk is obtained.

MOUNTAIN LIMESTONE, or **CARBONIFEROUS LIMESTONE**. A series of limestone strata of marine origin, usually forming the lowest member of the Coal Measures.

MOYA. A term applied in South America to mud poured out from volcanos during eruptions.

MULTILOCULAR. Many-chambered; a term applied to those shells which, like the nautilus, ammonite, and others, are divided into many compartments. *Etym.*, *multus*, many, and *loculus*, a partition.

MURIATE OF SODA. The scientific name for common culinary salt, because it is composed of muriatic acid and the alkali soda.

MUSACEÆ. A family of tropical monocotyledonous plants, including the banana and plantains.

MUSCHELKALK. A limestone, belonging to the Upper New Red Sandstone group. Its position is between the Magnesian Limestone and the Lias. This formation has not yet been found in England, and the German name is adopted by English geologists. The word means shell-limestone. *Etym.*, *muschel*, shell, and *kalkstein*, limestone.

NAPHTHA. A very thin, volatile, inflammable, and fluid mineral substance, of which there are springs in many countries, particularly in volcanic districts.

NENUPHAR. A yellow water-lily.

NEW RED SANDSTONE. A formation so named, because it consists chiefly of sandy and argillaceous strata, the predominant colour of which is brick-red, but containing portions which are of a greenish-grey. These occur often in spots and stripes, so that the series has sometimes been called the variegated sandstone. This formation is divided into the Upper New Red in which the Muschelkalk is included, and the Lower New Red of which the Magnesian Limestone is a member.

NODULE. A rounded irregular-shaped lump or mass. *Etym.*, diminutive of *nodus*, knot.

NORMAL GROUPS. Groups of certain rocks taken as a rule or standard. *Etym.*, *norma*, rule or pattern.

NUCLEUS. A solid central piece, around which other matter is collected. The word is Latin for kernel.

NUMMULITES. An extinct genus of the order of molluscous animals, called Cephalopoda, of a thin lenticular shape, internally divided into small chambers. *Etym.*, *nummus*, Latin for money, and *λίθος*, *lithos*, stone, from its resemblance to a coin.

OBSIDIAN. A volcanic product, or species of lava, very like common green bottle-glass, which is almost black in large masses, but semi-transparent in thin fragments. Pumice-stone is obsidian in a frothy state; produced, most probably, by water that was contained in or had access to the melted stone, and converted into steam. There are very often portions in masses of solid obsidian, which are partially converted into pumice.

OCHRE. A yellow powder, a combination of some earth with oxide of iron.

OGYGIAN DELUGE. A great inundation mentioned in fabulous history, supposed to have taken place in the reign of Ogyges in Attica, whose death is fixed in Blair's Chronological Tables in the year 1764 before Christ. See Vol. II. p. 140.

OLD RED SANDSTONE. A formation immediately below the Carboniferous Group. The term Devonian has been recently proposed for strata of this age, because in Devonshire they are largely developed, and contain many organic remains.

OLIVINE. An olive-coloured, semi-transparent, simple mineral, very often occurring in the form of grains and of crystals in basalt and lava.

OOLITE, OOLITIC. A limestone; so named, because it is composed of rounded particles, like the roe or eggs of a fish. The name is also applied to a large group of strata, characterized by peculiar fossils, in which limestone of this texture occurs.
Etym., *oos*, *oen*, egg, and *lithos*, stone.

OPALIZED WOOD. Wood petrified by siliceous earth, and acquiring a structure similar to the simple mineral called opal.

OPHIDIOUS REPTILES. Vertebrated animals, such as snakes and serpents. *Etym.*, *ophis*, *ophis*, a serpent.

ORGANIC REMAINS. The remains of animals and plants (*organized bodies*) found in a fossil state.

ORTHOCERATA, or ORTHOCERÆ. An extinct genus of the order of molluscous animals, called Cephalopoda, that inhabited a long-chambered conical shell, like a straight horn. *Etym.*, *opos*, *orthos*, straight, and *kepas*, *ceras*, horn.

OSSOUS BRECCIA. The cemented mass of fragments of bones of extinct animals found in caverns and fissures. *Osseus* is a Latin adjective, signifying bony.

OSTEOLGY. That division of anatomy which treats of the bones; from *οστεον*, *osseum*, bone, and *λόγος*, *logos*, a discourse.

OUTLIERS. When a portion of a stratum occurs at some distance, detached from the general mass of the formation to which it belongs, some practical mineral surveyors call it an *outlier*, and the term is adopted in geological language.

OVATE. The shape of an egg. *Etym.*, *oūm*, egg.

OVIPOSITING. The laying of eggs.

OXIDE. The combination of a metal with oxygen; rust is oxide of iron.

OXYGEN. One of the constituent parts of the air of the atmosphere; that part which supports life. For a further explanation of the word, consult elementary works on chemistry.

PACHYDERMATA. An order of quadrupeds, including the elephant, rhinoceros, horse, pig, &c., distinguished by having thick skins. *Etym.*, *παχυς*, *pachys*, thick, and *δέρμα*, *derma*, skin or hide.

PACHYDERMATOUS. Belonging to Pachydermata.

PALÆOTHERIUM, PALEOTHÈRE. A fossil extinct quadruped, belonging to the order Pachydermata, resembling a pig, or tapir, but of great size. *Etym.*, *παλαιος*, *palaios*, ancient, and *θηριον*, *therion*, wild beast.

PALÆONTOLOGY. The science which treats of fossil remains, both animal and vegetable. *Etym.*, *παλαιος*, *palaios*, ancient, *οντα*, *onta*, beings, and *λόγος*, *logos*, a discourse.

PELAGIAN, PELAGIC. Belonging to the deep sea. *Etym.*, *pelagus*, sea.

PIPERINO. An Italian name for a particular kind of volcanic rock, formed, like tuff, by the cementing together of volcanic sand, cinders, or scoriae, &c.

PETROLEUM. A liquid mineral pitch, so called because it is seen to ooze like oil out of the rock. *Etym.*, *petra*, rock, and *oleum*, oil.

PHΛENOGAMOUS or PHANEROGAMIC PLANTS. A name given by Linnæus to those plants in which the reproductive organs are apparent. *Etym.*, *φανερος*, *phaneros*, evident, or *φαίνω*, *phaino*, to show, and *γάμος*, *gamos*, marriage.

PHLEGRAEAN FIELDS. Campi Phlegrei, or "the Burnt Fields."

The country around Naples, so named by the Greeks, from the traces of igneous action every where visible.

PHONOLITE. See "Clinkstone."

PHRYGANEA. A genus of four-winged insects, the larvæ of which, called caddis-worms, are used by anglers as a bait.

PHYSICS. The department of science which treats of the properties of natural bodies, laws of motion, &c. ; sometimes called natural philosophy and mechanical philosophy. *Etym.*, φύσις, *physis*, nature.

PHYTOLOGY, PHYTOLOGICAL. The department of science which relates to plants — synonymous with botany and botanical. *Etym.*, φυτόν, *phyton*, plant, and λόγος, *logos*, discourse.

PHYTOPHAGOUS. Plant-eating. *Etym.*, φυτόν, *phyton*, plant, and φαγεῖν, *phagein*, to eat.

PISOLITE. A stone possessing a structure like an agglutination of pease. *Etym.*, πίσον, *pison*, pea, and λίθος, *lithos*, stone.

PISTIA. Vol. III. p. 126. The plant mentioned by Malte-Brun is probably the *Pistia Stratiotes*, a floating plant, related to English duck-weed, but very much larger.

PIT COAL. Ordinary coal; called so, because it is obtained by sinking pits in the ground.

PITCHSTONE. A rock of a uniform texture, belonging to the unstratified and volcanic classes, which has an unctuous appearance like indurated pitch.

PLASTIC CLAY. One of the beds of the Eocene Tertiary Period; so called, because it is used for making pottery. The formation to which this name is applied is a series of beds chiefly sands, with which the clay is associated. *Etym.*, πλαστώ, *plasso*, to form or fashion.

PLESIOSAURUS. A fossil extinct amphibious animal, resembling the saurian, or lizard and crocodile tribe. *Etym.*, πλησιον, *plesion*, near to, and σαῦρα, *saura*, a lizard.

PLIOCENE, OLDER and NEWER. Two divisions of the tertiary period which are the most modern, and of which the largest part of the fossil shells are of recent species. *Etym.*, πλειων, *pleion*, more, and καίνος, *kainos*, recent.

PLUTONIC ACTION. The influence of volcanic heat and other subterranean causes under pressure.

PLUTONIC ROCKS. Granite, porphyry, and other igneous rocks,

supposed to have consolidated from a melted state at a great depth from the surface.

POLYPARIA. CORALS. A numerous class of invertebrated animals, belonging to the great division called Radiata.

PORPHYRY. An unstratified or igneous rock. The term is as old as the time of Pliny, and was applied to a red rock with small, angular, white bodies diffused through it, which are crystallized felspar, brought from Egypt. The term is hence applied to every species of unstratified rock in which detached crystals of felspar or some other mineral are diffused through a base of other mineral composition, *Etym.*, πορφυρα, *porphyra*, purple.

PORTLAND LIMESTONE, PORTLAND BEDS. A series of limestone strata, belonging to the upper part of the Oolite Group, found chiefly in England in the island of Portland on the coast of Dorsetshire. The great supply of the building stone used in London is from these quarries.

Pozzuolana. Volcanic ashes, largely used as mortar for buildings, similar in nature to what is called in this country Roman cement. It gets its name from Puzzuoli, a town in the bay of Naples, from which it is shipped in large quantities to all parts of the Mediterranean.

PRECIPITATE. Substances which having been dissolved in a fluid, are separated from it by combining chemically and forming a solid, which falls to the bottom of the fluid. This process is the opposite to that of chemical solution.

PRODUCTA. An extinct genus of fossil bivalve shells, occurring only in the older secondary rocks. It is closely allied to the living genus *Terebratula*.

PTERODACTYL. A flying reptile: species of this genus have been found in the Oolite and Muschelkalk. Some of the finger joints are lengthened, so as to serve as the expansors of a membranous wing. Hence the name *wing-fingered*. *Etym.*, πτερον, *pteron*, a wing, and δακτυλος, *dactylos*, a finger.

PUBESCENCE. The soft hairy down on insects. *Etym.*, *pubesco*, the first growth of the beard.

PUDDINGSTONE. See "Conglomerate."

PUMICE. A light spongy lava, chiefly felspathic, of a white colour, produced by gases, or watery vapour getting access to the particular kind of glassy lava called obsidian, when in

a state of fusion — it may be called the froth of melted volcanic glass. The word comes from the Latin name of the stone, *pumex*.

PURBECK LIMESTONE, PURBECK Beds. Limestone strata, belonging to the Wealden Group, which intervenes between the Green-sand and the Oolite.

PYRITES (Iron). A compound of sulphur and iron, found usually in yellow shining crystals like brass, and in almost every rock, stratified and unstratified. The shining metallic bodies so often seen in common roofing slate, are a familiar example of the mineral. The word is Greek, and comes from *πῦρ*, *pyr*, fire; because, under particular circumstances, the stone produces spontaneous heat, and even inflammation.

PYROMETER. An instrument for measuring intense degrees of heat.

QUADRUMANA. The order of mammiferous animals to which apes belong. *Etym.*, *quadrus*, a derivative of the Latin word for the number four, and *manus*, hand, the four feet of those animals being in some degree usable as hands.

QUA-QUA-VERSAL DIP. The dip of beds to all points of the compass around a centre, as in the case of beds of lava round the crater of a volcano. *Etym.*, *quā-quā versum*, on every side.

QUARTZ. A German provincial term, universally adopted in scientific language for a simple mineral composed of pure silex, or earth of flints: rock-crystal is an example.

QUARTZITE OR QUARTZ ROCK. An aggregate of grains of quartz, sometimes passing into compact quartz.

RED MARL. A term often applied to the New Red Sandstone.

RETICULATE. A structure of cross lines, like a net, is said to be reticulated, from *rete*, a net.

ROCK SALT. Common culinary salt, or muriate of soda, found in vast solid masses or beds, in different formations, extensively in the New Red Sandstone formation, as in Cheshire; and it is then called *rock-salt*.

RUBBLE. A term applied by quarry-men to the upper fragmentary and decomposed portion of a mass of stone.

RUMINANTIA. Animals which ruminate or chew the cud, such as the ox, deer, &c. *Etym.*, the Latin verb *rumino*, meaning the same thing.

SACCHAROID, SACCHARINE. When a stone has a texture resembling that of loaf-sugar. *Etym.*, *sacchar*, sugar, and *eidos*, *eides*, form.

SALIENT ANGLE.

In a zigzag line, *a a* are the salient angles, *b b*

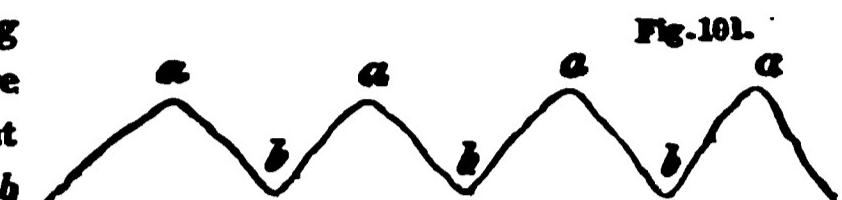


Fig. 101.

the re-entering angles. *Etym.*, *salire*, to leap or bound forward.

SALT SPRINGS. Springs of water containing a large quantity of common salt. They are very abundant in Cheshire and Worcestershire, and culinary salt is obtained from them by mere evaporation.

SANDSTONE. Any stone which is composed of an agglutination of grains of sand, whether calcareous, siliceous, or of any other mineral nature.

SAURIAN. Any animal belonging to the lizard tribe. *Etym.*, *saups*, *saura*, a lizard.

SCHIST is often used as synonymous with slate; but it may be very useful to distinguish between a schistose and a slaty structure. The hypogene or primary *schists*, as they are termed, such as gneiss, mica-schist, and others, cannot be split into an indefinite number of parallel laminæ, like rocks which have a true slaty cleavage. The uneven schistose layers of mica-schist and gneiss are probably layers of deposition, which have assumed a crystalline texture. See "Cleavage." *Etym.*, *schistus*, adj. Latin, that which may be split.

SCHISTOSE ROCKS. See "Schist."

SCORIAE. Volcanic cinders. The word is Latin for cinders.

SEAMS. Thin layers which separate two strata of greater magnitude.

SECONDARY STRATA. An extensive series of the stratified rocks which compose the crust of the globe, with certain characters in common, which distinguish them from another series below them called *primary*, and from a third series above them called *tertiary*.

SECULAR REFRIGERATION. The periodical cooling and consolid-

ation of the globe from a supposed original state of fluidity from heat. *Sæculum*, age or period.

SEDIMENTARY Rocks are those which have been formed by their materials having been thrown down from a state of suspension or solution in water.

SELENITE. Crystallized gypsum, or sulphate of lime — a simple mineral.

SEPTARIA. Flattened balls of stone, generally a kind of iron-stone, which, on being split, are seen to be separated in their interior into irregular masses. *Etym.*, *septa*, inclosures.

SERPENTINE. A rock usually containing much magnesian earth, for the most part unstratified, but sometimes appearing to be an altered or metamorphic stratified rock. Its name is derived from frequently presenting contrasts of colour, like the skin of some serpents.

SHALE. A provincial term, adopted by geologists, to express an indurated slaty clay. *Etym.*, German *schalen*, to peel, to split.

SHELL MARL. A deposit of clay, peat, and other substances mixed with shells, which collects at the bottom of lakes.

SHINGLE. The loose and completely water-worn gravel on the sea-shore.

SILEX. The name of one of the pure earths, being the Latin word for *flint*, which is wholly composed of that earth. French geologists have applied it as a generic name for all minerals composed entirely of that earth, of which there are many of different external forms.

SILICA. One of the pure earths. *Etym.*, *silex*, flint, because found in that mineral.

SILICATE. A chemical compound of silica and another substance, such as silicate of iron. Consult elementary works on chemistry.

SILICEOUS. Of or belonging to the earth of flint. *Etym.*, *silex*, which see. A siliceous rock is one mainly composed of silex.

SILICIFIED. Any substance that is petrified or mineralized by siliceous earth.

SILT. The more comminuted sand, clay, and earth, which is transported by running water. It is often accumulated by currents in banks. Thus the mouth of a river is silted up

when its entrance into the sea is impeded by such accumulation of loose materials.

SIMPLE MINERAL. Individual mineral substances, as distinguished from rocks, which last are usually an aggregation of simple minerals. They are not simple in regard to their nature ; for, when subjected to chemical analysis, they are found to consist of a variety of different substances. Pyrites is a simple mineral in the sense we use the term, but it is a chemical compound of sulphur and iron.

SINTER, CALCAREOUS OR SILICKOUS. A German name for a rock precipitated from mineral waters. *Etym.*, *sintern*, to drop.

SLATE. See "Cleavage" and "Schist."

SOLFATARA. A volcanic vent from which sulphur, sulphureous, watery, and acid vapours and gases are emitted.

SPORULES. The reproductive corpuscula (minute bodies) of cryptogamic plants. *Etym.*, *σπορα, spora*, a seed.

STALACTITE. When water holding lime in solution deposits it as it drops from the roof of a cavern, long rods of stone hang down like icicles, and these are called *stalactites*. *Etym.*, *σταλαζω, stalazo*, to drop.

STALAGMITE. When water holding lime in solution drops on the floor of a cavern, the water evaporating leaves a crust composed of layers of limestone : such a crust is called *stalagmite*, from *σταλαγμα, stalagma*, a drop, in opposition to *stalactite*, which see.

STATICAL FIGURE. The figure which results from the equilibrium of forces. From *στατος, statos*, stable, or standing still.

STERNUM. The breast-bone, or the flat bone occupying the front of the chest.

STILBITE. A crystallized simple mineral, usually white, one of the Zeolite family, frequently included in the mass of the Trap-rocks.

STRATIFIED. Rocks arranged in the form of *strata*, which see.

STRATIFICATION. An arrangement of rocks in *strata*, which see.

STRATA, STRATUM. The term *stratum*, derived from the Latin verb *struo*, to strew or lay out, means a bed or mass of matter spread out over a certain surface by the action of water, or in some cases by wind. The deposition of successive layers of sand and gravel in the bed of a river, or in a canal, affords a perfect illustration both of the form and origin of stratification,

A large portion of the masses constituting the earth's crust are thus stratified, the successive strata of a given rock preserving a general parallelism to each other; but the planes of stratification not being perfectly parallel throughout a great extent like the planes of *cleavage*, which see.

STRIKE. The direction or line of bearing of strata, which is always at right angles to their prevailing dip.

STUFS. Jets of steam issuing from fissures in volcanic regions at a temperature often above the boiling point.

SUBAPENNINES. Low hills which skirt or lie at the foot of the great chain of the Apennines in Italy. The term Subapennine is applied geologically to a series of strata of the Older Pliocene Period.

SYENITE. A kind of granite; so called, because it was brought from Syene in Egypt.

TALUS. When fragments are broken off by the action of the weather from the face of a steep rock, as they accumulate at its foot, they form a sloping heap, called a talus. The term is borrowed from the language of fortification, where *talus* means the outside of a wall of which the thickness is diminished by degrees, as it rises in height, to make it the firmer.

Tarsi. The feet in insects, which are articulated, and formed of five or a less number of joints.

TERTIARY STRATA. A series of sedimentary rocks, with characters which distinguish them from two other great series of strata — the secondary and primary — which lie beneath them.

TESTACEA. Molluscous animals, having a shelly covering. *Etym.*, *testa*, a shell, such as snails, whelks, oysters, &c.

THERMAL. Hot. *Etym.*, *θέρμος*, *thermos*, hot.

THERMO-ELECTRICITY. Electricity developed by heat.

THIN OUT. When a stratum, in the course of its prolongation in any direction, becomes gradually less in thickness, the two surfaces approach nearer and nearer; and when at last they meet, the stratum is said to thin out or disappear.

TRACHYTE. A variety of lava essentially composed of glassy felspar, and frequently having detached crystals of felspar in the base or body of the stone, giving it the structure of por-

phyry. It sometimes contains hornblende and augite; and when these last predominate, the trachyte passes into the varieties of trap called Greenstone, Basalt, Dolorite, &c. The term is derived from *τραχύς, trachus*, rough, because the rock has a peculiar rough feel.

TRAP and TRAPPEAN Rocks. Volcanic rocks composed of felspar, augite, and hornblende. The various proportions and state of aggregation of these simple minerals, and differences in external forms, give rise to varieties, which have received distinct appellations, such as Basalt, Amygdaloid, Dolorite, Greenstone, and others. The term is derived from *trappa*, a Swedish word for stair, because the rocks of this class sometimes occur in large tabular masses, rising one above another, like steps.

TRAVERTIN. A white concretionary limestone, usually hard and semi-crystalline, deposited from the water of springs holding lime in solution.—*Etym.* This stone was called by the ancients Lapis Tiburtinus, the stone being formed in great quantity by the river Anio, at Tibur, near Rome. Some suppose travertin to be an abbreviation of trasteverino from *trans-tiburtinus*.

TAIPOLL. The name of a powder used for polishing metals and stones, first imported from Tripoli, which, as well as a certain kind of siliceous stone of the same name, has been lately found to be composed of the flinty cases of Infusoria.

TRORPHI, of Insects. Organs which form the mouth, consisting of an upper and under lip, and comprising the parts called mandibles, maxillæ, and palpi.

TUFA, CALCAREOUS. A porous rock deposited by calcareous waters on their exposure to the air, and usually containing portions of plants and other organic substances incrusted with carbonate of lime. The more solid form of the same deposit is called "travertin," into which it passes.

TUFA, VOLCANIC. See "Tuff."

TUFACEOUS. A rock with the texture of tuff, or tufa, which see.

TUFF, or TUFA, VOLCANIC. An Italian name for a variety of volcanic rock of an earthy texture, seldom very compact, and composed of an agglutination of fragments of scoria and loose materials ejected from a volcano.

TURBINATED. Shells which have a spiral or screw-form structure.

Etym., *turbanus*, made like a top.

TURRILITE. An extinct genus of chambered shells, allied to the Ammonites, having the siphuncle near the dorsal margin.

UNCONFORMABLE. See "Conformable."

UNOXIDIZED, UNOXIDATED. Not combined with oxygen.

VEINS, MINERAL. Cracks in rocks filled up by substances different from the rock, which may either be earthy or metallic. Veins are sometimes many yards wide; and they ramify or branch off into innumerable smaller parts, often as slender as threads, like the veins in an animal, hence their name.

VERTEBRATED ANIMALS. A great division of the animal kingdom, including all those which are furnished with a back-bone, as the Mammalia, birds, reptiles, and fishes. The separate joints of the back-bone are called *vertebræ*, from the Latin verb *verto*, to turn.

VESICLE. A small, circular, inclosed space, like a little bladder.

Etym., diminutive of *vesica*, Latin for a bladder.

VITRIFICATION. The conversion of a body into glass by heat.

VOLCANIC BOMBS. Volcanos throw out sometimes detached masses of melted lava, which, as they fall, assume rounded forms (like bomb-shells), and are often elongated into a pear shape.

VOLCANIC FOCI. The subterranean centres of action in volcanos, where the heat is supposed to be in the highest degree of energy.

WACKE. A rock nearly allied to basalt, of which it may be regarded as a soft and earthy variety.

WARP. The deposit of muddy waters, artificially introduced into low lands. See Vol. II. p. 109.

ZEOLITE. A family of simple minerals, including stilbite, mesotype, analcime, and some others, usually found in the trap or volcanic rocks. Some of the most common varieties swell or boil up when exposed to the blow-pipe, and hence the name of ζεω, *zeo*, to boil, and λιθος, *lithos*, stone.

ZOOHYTES. Corals, sponges, and other aquatic animals allied to them; so called because, while they are the habitation of animals, they are fixed to the ground, and have the forms of plants. *Etym.*, ζωον, *zoon*, animal, and φυτον, *phyton*, plant.

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